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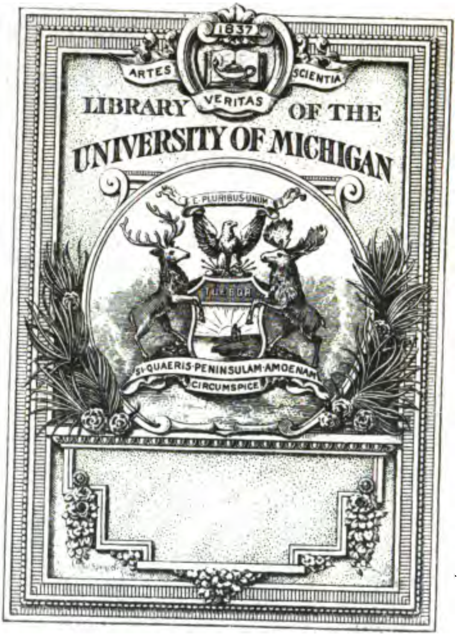
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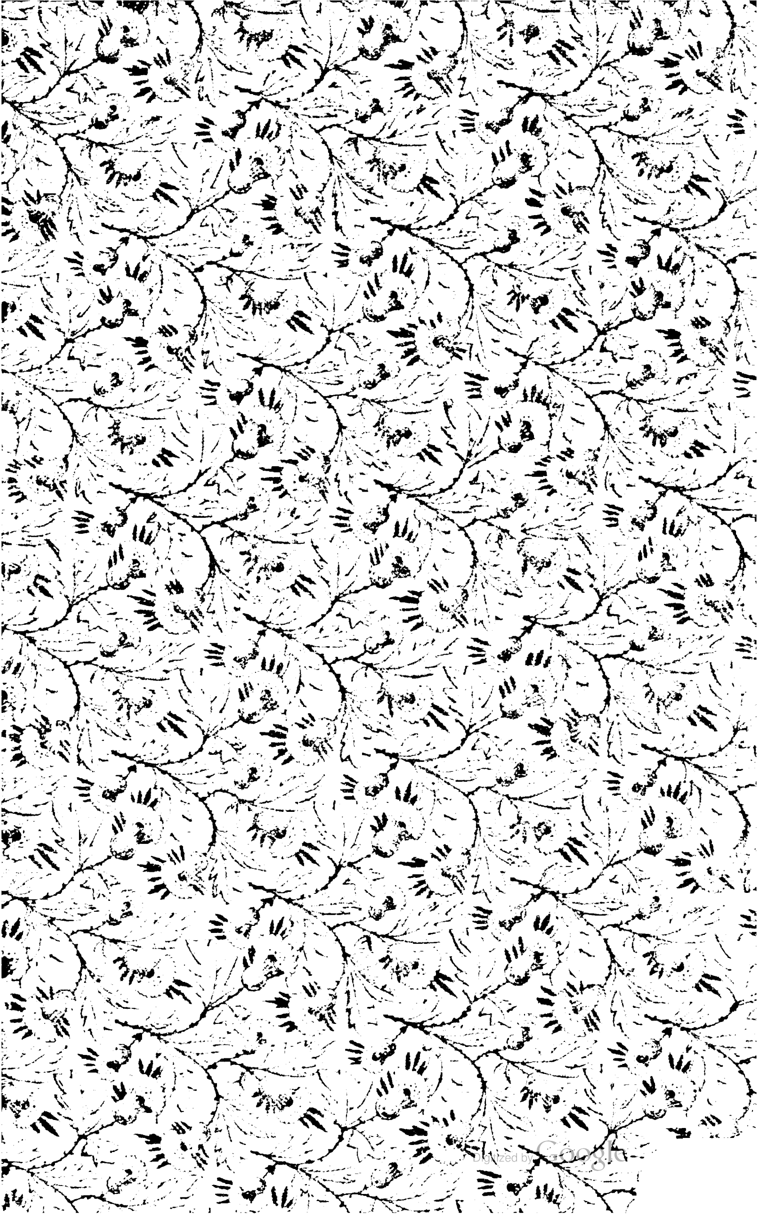

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# FACTS IN CHEMISTRY:

ILLUSTRATED WITH

NUMEROUS EXPERIMENTS,

AND UPWARDS OF

TWO HUNDRED AND EIGHTY

QUESTIONS ADAPTED FOR BEGINNERS.

BY

## SURGEON LOVER,

LECTURER ON CHEMISTRY AND EXPERIMENTAL PHILOSOPHY IN DUBLIN AND
THE DIFFERENT MECHANICS' INSTITUTIONS IN IRELAND.

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# FACTS IN CHEMISTRY.

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## ARRANGED FOR SCHOOLS.

BY

**WILLIAM LOVER,**

Member of College of Surgeons, L.; Associate Member of the Academic
Association, Dublin; and Lecturer on Chemistry and Experimental
Philosophy in the Academies of Dublin.

1st Part.—CHEMICAL ATTRACTION—HEAT, AND SIMPLE NON-METALLIC BODIES.
2nd Part.—ACIDS, ALKALIES, AND EARTHS.
3rd Part.—THE METALS.

> "I know of no part of the almighty and all-wise Creator's works which is unimportant—and I think *the child is the better* because he has become possessed of a knowledge of a portion of those works by the wholesome and agreeable exercise of his faculties."—Sir Philip Crampton's Zoological Lecture.

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DEDICATED

WITH FEELINGS OF RESPECT AND GRATITUDE,

TO

**MICHAEL DONOVAN, ESQ., M. R. I. A.**

FORMERLY

PROFESSOR OF CHEMISTRY TO

THE APOTHECARIES' HALL,

BY

HIS INDEBTED PUPIL,

*The Author.*

# PREFACE.

ONE of the remarkable characteristics of the present day is the existence of a spirit for the diffusion of a knowledge of the physical sciences, which have hitherto been expounded only in a college or a professed school of science; that time has happily passed away, for society begins to feel that it is an essential exercise of reason to investigate the relations which connect man with his Creator.

We see this great change apparent in the establishment of mechanic institutions, and in the introduction of those subjects into *general education*. With respect to mechanic institutions we may safely say that they are among the best guarantees for a people's advancement; for it is admitted that science opens sources of intellectual pleasure, which gra-

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dually create a distaste for those of a sensual nature. The change is also apparent in the system which begins to prevail, of instructing youth of both sexes in the elements of the physical sciences, which will not strain their intellectual powers, but tend to form habits of inquiry and research for a subsequent period of life.

Having been engaged for some years past in laying those subjects before the young mind by lecture, I can fearlessly assert that, with much care on the part of the teacher, and some attention on that of the pupil, the *leading* facts of science can be *comprehended*, and their importance *appreciated* at the age of 14 as well as at 24.

In advocating the system here alluded to, I trust that none will suppose me capable of wishing to undervalue the importance of *classical* knowledge; the attempt to do so would not only be unwise but dangerous, as it would tend to destroy one of the foundations of knowledge. It may be here noticed that parents are now beginning to feel the importance of directing the *female* mind to such investigations. If such a system could be generally introduced into female education, it would decidedly place woman in that position in society which her intellectual powers justly entitle her to.

I trust the reader will bear in mind that I do not profess to teach chemistry by the following treatise, or by my elementary lectures; the object of both is merely to awaken a spirit of inquiry. These pages, perhaps, may be compared to the *groundwork* which is laid upon the artist's canvas, *without* which preparation the skill of a Titian would be fruitless, for all the colours mingling with each other would prevent the harmonious outlines from being formed.

Dublin, 30th April, 1842.

# FACTS IN CHEMISTRY.

1. The province of Natural Philosophy, in its most comprehensive sense, investigates the laws to which matter, that is, the material world, is subject—a law in this sense being a rule prescribed by the Creator by which the same event invariably occurs under similar circumstances, such rules collectively being termed *the laws of nature*.

2. In proportion as man extended his researches, he was under the necessity of dividing science—which, from the Latin *scio*, to know, signifies knowledge—into various branches:—1st. Mathematical Science, which considers number and quantity, subdivided into *arithmetic* (Greek, *αριθμος*, number) and *geometry* (Greek, *γεα*, earth, *μετρον*, measure.) These branches are purely the result of reasoning; for frequently they investigate subjects that have no existence but in the mind, and therefore have no properties like matter or substantial agents.

3. The second great division, termed the *Physical Sciences*, or Physics (derivation, *φυσισ*, nature), which

are based upon observation and experiment. They are the reverse of the mathematical sciences, for they consider the structure and motions of bodies; their connexion with each other, and the influence which they mutually exert upon other agents. These comprehensive subjects are subdivided into *Natural Philosophy*—which now signifies the investigation of the laws of motion and the state of rest, and the properties of material agents, such as water, air, steam, &c., which produce certain effects, termed mechanical, upon passive bodies: for example, setting them in motion or at rest, or *partially* altering their form by pressure *without* destroying their composition.

4. The second division of the Physical Sciences treats of the *composition* and properties of all existing bodies, animate or inanimate. These subjects, being extensive, have been thus subdivided:—If we speak of the properties of bodies with respect to heat, their composition, or their action—termed chemical, in contradistinction to mechanical—upon each other, by which the *total* destruction of their *form* or *properties* ensues, we term the subject *Chemistry*. Two other subdivisions, Mineralogy and Geology, are closely allied to Chemistry. The first teaches us to recognise and *classify* the various objects of *inorganic* nature, so termed as they are without organs—such as heart, stomach, &c.—and, being usually obtained from the earth by mining, are called *Minerals*. *Geology* (deriv. γεα, the earth, and λογος, a narrative) considers the structure of the earth and the changes which its strata have undergone. *Anatomy*

(deriv. *ανα*, through, and *τεμνω*, to cut) investigates the animal structure ; and *Animal Physiology* (deriv. *φυσις*, nature, and *λογος*, a narrative) considers the *uses* of the parts which Anatomy has disclosed. *Zoology* (deriv. *ζωον*, an animal, and *λογος*, a narrative) differs from the two preceding branches, as it *classifies* animals, and examines their external appearance without reference to internal structure. *Botany* (deriv. *βοτανη*, a plant) classifies the productions of the vegetable kingdom, and *Vegetable Physiology* examines their structures. The term *Natural History* is applied to signify the classification of natural objects belonging to the animal, vegetable, and mineral kingdoms ; therefore it embraces Zoology, Botany, and Mineralogy.

## QUESTIONS.

1. What did Natural Philosophy originally signify ?
2. What is implied by the term, a law of nature ?
3. What is the derivation of the term Science ?
4. What is the object of Mathematical Science, and how is it divided ?
5. What are the derivations of Arithmetic and Geometry ?
6. How do the Physical Sciences, or Physics, differ from the Mathematical Sciences ?
7. What is the derivation of the term Physical ?
8. Enumerate the general subdivision of the Physical Sciences ?
9. What is, at present, the definition of Natural Philosophy ?
10. How does Chemistry differ from Natural Philosophy ?
11. What distinction exists between Mineralogy and Geology ?

12. Why are Minerals termed inorganic bodies?

13. Does Anatomy differ from Animal Physiology?

14. What is Zoology?

15. Explain the difference between Botany and vegetable Physiology?

16. What does Natural History signify?

*Note.*—The derivations should be particularly attended to.

## THE ORIGIN OF CHEMISTRY.

5. From what has been stated, chemistry may be defined thus:—The science which investigates the properties of bodies in their simple or compound state—their action upon each other, termed chemical, by mixture or heat, by which *new* combinations, possessing *different* properties from the original bodies, are formed—sometimes the properties remain while the form and appearances are *totally* destroyed.

The science, as it now exists, is altogether of modern creation, although it was based upon discoveries made at a very early period in the history of man. The Arabians, when a distinguished people, originally directed their attention to the subject—their views were, that by exposing bodies to heat, they could obtain new combinations, and procure three important objects—1st. Gold from the baser metals; 2d. The elixir of life; and 3d. The universal solvent, that would dissolve every thing. As the science had such an exalted aim, it was termed Alchemy; the derivation is extremely uncertain. The professors were termed *alchemists*. It appears that the Crusaders, on their return to Europe, first introduced the art from Palestine. All classes of society immediately became infatuated; and even monarchs visited the laboratory of the alchemist, whose language was shrouded in mystery, and who was supposed to possess supernatural agency. At last, when the professors found that their object was unattainable, they made their art the instrument of extortion. Edward I., it is said, was duped by Raymond Lully, an alchemist. Many families of distinction having been ruined, the attention of the legislature was directed to the subject, as we find by an act passed in the reign of Henry IV. prohibiting his subjects from attempting to make gold or silver under the pain of felony. Alchemy soon after sunk into disrepute, leaving its ashes, from which the phœnix, *Chemistry*, arose, that was destined to become not the instrument of crime, but the most exalted science that ministers to the happiness of mankind. If we but look around us, we see the result of some chemical process. The metals, for example, presented to us by the Creator generally in a useless state, are fashioned by this stupendous science into ornaments, bolts, leaves, salts, and fluids. By its aid we obtain our various colours for painting, writing, dyeing, &c.; and by the same power we destroy colour, as in bleaching. We see its operation in the formation of transparent glass from opaque materials, and of soap from two enemies, oil and water. It is chemistry that presents us with gas and steam; and already it promises at no distant period, either partially or totally, to supplant the latter favourite by another, the electric fluid; and thus will that mighty agent that, as lightning, carries desolation in its course, be harnessed to the massive train upon the railroad, or urge the ship in safety against wind and tide. If chemisty have done so much for man, are we not justified in showing the young mind *how* she produces her effects; for

> "To know
> That which before us lies in daily life
> Is the prime wisdom."—MILTON.

QUESTIONS.

17. What is the definition of our present science, chemistry?
18. Where had it its origin?
19. What object had the alchemists in view?
20. Who introduced alchemy into Europe?
21. Why did Henry IV. prohibit his subjects from practising the art?

## PROPERTIES OF MATTER.

6. As bodies which are the subject of chemical investigation are composed of matter, which implies any thing that has substance, it will be essential, before we consider the outline of chemistry, to lay before the young mind certain important facts connected with matter, which comes under our observation in three different states—the solid, the liquid,

and the gas—the latter, in the strict sense, signifying matter which cannot be converted into a liquid or solid by the coldest climate, thus differing from a vapour, steam for example, which, by exposure to cold, returns to the liquid state, the process being termed *condensation.*

7. All bodies are composed of minute portions, termed *atoms,* which can only be separated by a chemical process. A mechanical one—grinding, termed trituration, for example—can reduce a body to the finest power, but not to atoms—for its *particles* can still further be divided by *solution,* which is a chemical process. At this point we arrive at the limit of *divisibility,* which means the capability of being divided. This is a universal property of matter.

### QUESTIONS.

22. In how many states is matter presented to our notice?
23. How does a gas differ from a vapour?
24. What is the difference between an atom and a particle?
25. Can we reduce a body to atoms by grinding?
26. What is the definition of divisibility?

---

8. Another is *impenetrability,* which implies that two bodies cannot occupy the same space at the same time. A familiar illustration of this law is inverting a wine glass in water; the air that occupies the inverted vessel will not allow the surrounding water to take possession of the space: upon this principle the *diving-bell* is constructed.

9. Impenetrability yields to a certain extent to another, *compressibility,* which produces some of the most familiar effects. In the case of the inverted wine-glass : although the air does not leave the vessel, it is forced into a smaller space by the pressure of the water above it, particularly if it be immersed to any considerable distance from the surface. It has been ascertained by means of the force-pump that air is so compressible that a hundred parts, say pints, can be forced into the space of one pint. This is technically expressed thus : air can be compressed into the hundredth part of its original volume. When alluding to air in this state the term *condensed* is substituted for *compressed.* It is to be particularly remembered that the term *compressed,* or *high pressure,* applied to steam, means that it occupies a smaller space without changing its condition—while *condensed* signifies that it has returned to the state of water.—(*Vide* 6.)

10. When bodies are compressed, another property, *elasticity* generally comes into operation, tending to restore them to their original condition—the air-gun offers an excellent illustration—the mechanism of which is easily explained :—condensed air confined in a copper vessel, being allowed to rush, by its elastic force, into the barrel of the gun, it projects the bullet to a greater or less distance, according to the extent of its condensation ; compressed steam, by the same principle, will burst the strongest vessel, if not allowed to escape by a safety-valve.

### QUESTIONS.

27. What property of matter prevents water from completely entering into an inverted wine-glass?

28. Why does it do so partially?

29. To what extent can air be condensed?

30. What is the difference between condensed air and condensed steam?

31. What property of matter allows the condensed air in the air-gun to propel the bullet?

---

## ATTRACTION.

The next property we have to consider requires particular attention; it is termed attraction, from the Latin *attraho*, to draw towards: observation and experiment have proved that it is an invariable law of nature, for bodies to attract, or tend to attract, other atoms of a *similar* or *dissimilar* nature. Without this unseen but mighty power, the earth would crumble into dust, and all its bodies be whirled into boundless space. According to the mode in which attraction acts, it receives different terms; for example, attraction of cohesion and gravitation; chemical attraction; magnetic, electrical, and capillary attraction: in the present work the three first will be noticed.

12. Attraction of cohesion (derivation *cohæreo*, to be joined together,) implies the property which the atoms of matter possess, of attracting atoms of *the same* nature. Although it is an universal law, the Creator has wisely ordained that it should exist in

different degrees of intensity in different bodies: the metals and solids exhibit this attraction most forcibly; the atoms of liquids which *move freely over each other*, are evidently not under the same control; and gases, which cannot be converted into liquids by the coldest climate, are evidently influenced by this law only in a slight degree. In the article on carbonic acid, it will be seen, that artificial cold, of an intense degree, can liquify some of the gases.

13. In the majority of cases it is *heat* which determines the intensity of attraction of cohesion. Water, for example, which exists in three states, steam, water, and ice, will prove the truth of this statement. When cooled down to 32 degrees, termed the freezing point on the thermometer of Fahrenheit, (*vide* 26,) attraction of cohesion is brought so forcibly into operation, that it becomes a solid, termed ice. On the contrary, when heat is applied, until the temperature reaches 212 degrees, the boiling point, this attraction is overcome to such an extent, that its atoms fly from each other to form steam, which occupies about 1728 times the space of the original quantity of water.

14. As we remove the pressure of the atmosphere by an air-pump from the surface of the fluid, a less portion of heat will be required to convert water into steam; or, in other words, water boils at a less temperature than 212 degrees, if atmospheric pressure be removed. The same effect is produced on the tops of high mountains, in which situations atmospheric pressure is less than at the level of the sea.

15. Tenacity, which prevents bodies from being torn, depends upon attraction of cohesion being exerted in an intense degree: some idea of its effects may be formed from the following illustrations:—a wire of iron, the most tenacious of the metals, the one-tenth of an inch in diameter, will support a weight of 450lbs.; silver wire, same diameter, 370lbs.; and lead wire only 29¼lbs.

### QUESTIONS.

32. What is the derivation of attraction of cohesion?

33. What does it imply?

34. Does it exist in the same intensity in all bodies?

35. Why does the intensity of attraction of cohesion vary in ice, water, and steam?

36. What space does steam occupy, compared with the volume of the original quantity of water?

37. Why does water boil with less heat under the exhausted receiver of an air-pump?

38. What does tenacity result from?

---

16. When the atoms of a body are few, and are at liberty to be moved freely, as is the case with liquids, we find that the cohesive force appears to collect them around a centre, thus forming a sphere; witness the dew-drop, or the globule of mercury.

In obedience to this law, the earth and the planetary system assumed the form of *spheres*, which, when set in rapid motion by the Divine will, brought centrifugal force into operation, and, tending to fly from their respective centres, were converted into *spheroids*, which differs from spheres, in having one diameter longer than the other. The equatorial diameter of the earth, for example, is longer than the polar. (In a work on chemistry, it would be unwise to enter into the subject of centrifugal force; it should, however, be explained to the pupil by the parent or preceptor.)

### QUESTIONS.

39. Why do fluids tend to assume the form of spheres?
40. Why is not the earth a sphere?
41. How does a sphere differ from a spheroid?

17. If the pupil can form an idea of the nature of attraction of cohesion from what has been said, it will, perhaps, not be difficult to follow up the investigation, by considering the subject of attraction of gravitation, which may be thus distinguished from the preceding. Attraction of cohesion tends to form a mass of the same nature, by collecting its atoms round a centre: this power only acts at insensible distances, that is, when the atoms are not apparently separated. Attraction of gravitation, on the contrary, which exists in large masses, as the sun, earth, and planetary system, operates upon other masses of a different nature, at immense distances. Without this invisible and stupendous power, termed by astronomers centripetal force, (deriv. *centrum*, a centre, and *peto*, to seek,) the planets would fly from the sun, and the satellites from the planets, by cen-

trifugal force; acted upon, however, by both powers, those revolving bodies take intermediate paths, termed their orbits, and thus the balance of nature is established.

### QUESTIONS.

42. How does attraction of cohesion differ from attraction of gravitation?

43. What other term do astronomers apply to the force, attraction of gravitation, and what is its derivation?

18. Like cohesive force, attraction of gravitation acts from the centre of the mass, towards which point all the bodies near its surface are forcibly drawn, thus receiving a property which is termed *gravity*, or weight; consequently, if we could reach the centre of the attracting mass, the earth, for example, weight would vanish, the body being attracted equally on all sides. It is hoped that the pupil will particularly impress this fact upon his memory, that as gravity or weight is the effect of gravitation, all bodies in nature must have weight, and that their pressure towards the centre producing friction in machinery, will for ever prevent him from obtaining perpetual motion, a mere vision, which has frequently cost men of mechanical ability years of anxiety and disappointment, perpetual motion only existing in the planetary system.

## QUESTIONS.

44. What is gravity or weight the effect of?

45. Why would not a body have weight at the centre of the earth?

46. What is friction in machinery produced by?

47. Can we obtain perpetual motion?

---

19. Chemical attraction is next to be considered. As this has peculiar reference to the following treatise, we must direct particular attention to it. We have seen that attraction of cohesion is the force which forms masses, by uniting atoms to atoms of *the same nature.* Chemical attraction, sometimes termed chemical affinity, can be easily distinguished from it by its forcing atoms of *dissimilar bodies,* to unite, forming new compounds, unlike the bodies of which they are composed, the process being termed *chemical combination.* It will be shown by experiment, that chemical action not only forms compounds, but destroys those which are natural or artificial, the process being termed *decomposition.* This is effected by mixture with other bodies, or by the agency of heat. It may be truly said, that chemical combination and decomposition constitute the foundation of chemistry. Numerous illustrations of combination and decomposition will be presented as we proceed; a few must be noticed here.

*Experiment* 1.—Breathe through a tube into a glass of transparent lime-water; in a short time the fluid will assume a *milky* appearance, arising from the dissolved lime combining with the invisible gas, termed carbonic acid, which we expel from the lungs by expiration, the dissolved lime and invisible carbonic acid, by chemical affinity, form a visible powder; carbonate of lime, which after some time falls to the bottom of the vessel, being insoluble in water, and is said to be *precipitated.*

*Experiment* 2.—So far we have combined two different bodies, now we are prepared to illustrate decomposition: pour a few drops of muriatic acid (spirit of salt,) into the vessel; by agitation the mixture will become again transparent, in consequence of the muriatic displacing the carbonic acid, which escapes in the state of gas; the muriatic uniting with the lime forming a new compound muriate of lime, which is soluble in water; the product of the first experiment is then said to be decomposed.

### QUESTIONS.

48. What is the difference between chemical attraction and attraction of cohesion?

49. What is implied by the term decomposition?

50. Why does lime-water assume a milky appearance when we breathe in it?

---

20. Chemical attraction does not come into operation unless some of the following conditions are observed: one or both of the bodies require to be presented in the state of atoms, (*vide* 7;) this is effected by *solution*, or *fusion*. The following illustrations forcibly display this law:—

*Experiment* 3.—Mix a small quantity of dried tartaric acid and bicarbonate of soda, exclude them from the air in a close vessel, and no chemical action ensues: throw them, on the contrary, into a glass of water, this process termed *solution*, reduces them to atoms, when instantly an appearance like boiling, termed *effervescence*, is produced, arising from the tartaric acid seizing the soda, forming a new compound, tartrate of soda, thus dislodging the carbonic acid, which, seeking its liberty, produces the *effervescence*. The above is the composition of soda-water powders.

*Experiment* 4.—Melt two ounces of tin and one ounce of lead in a ladle; by this process, termed *fusion*, chemical attraction comes into operation, and the compound is termed soft solder, used by plumbers: this illustrates combination by heat.

*Experiment* 5 will give some idea of *decomposition*, by the same agent. Subject a piece of limestone, chalk, or marble to heat in a crucible, in a short time it will be found to have acquired a caustic taste, and can be slacked by water, like lime; in fact, it is the process of lime-burning on a miniature scale: the causticity arises from the carbonic acid, which neutralized it, having been expelled.

From what has been stated, it will be seen that *solution* and *fusion* are generally essential conditions to enable us to bring chemical action into play.

### QUESTIONS.

51. Why do not tartaric acid and bicarbonate of soda act upon each other while dry?

52. What is implied by the term solution?

53. How does it differ from fusion?

54. What is the difference between boiling and effervescence?

55. Give an illustration of chemical attraction and decomposition by heat.

---

21. There are three kinds of chemical attraction: the first, termed simple, as shown by experiment 4, consists in simple bodies acting on each other; or the same term is applied to the case of *compounds* uniting *without decomposition*, (*vide* experiment 1;) lime and carbonic acid, being both compound bodies: simple attraction may also be seen in a compound decomposing another compound, without being itself decomposed. In experiment 3, for example, the carbonate of soda is decomposed by tartaric acid, a compound which unites with the soda.

[The author trusts he will be excused for having here so frequently used the term compound, in the attempt to render this part of the subject intelligible.]

### QUESTIONS.

56. In simple chemical attraction, is it essential that simple bodies alone should be employed?

57. Can you give an illustration of simple attraction where one of the bodies is decomposed?

---

22. The second kind of chemical attraction is termed *compound*. When two compound bodies

decompose *each other*, as will be illustrated by the following experiment, (No. 6,) some term it double decomposition, dissolve a small quantity of potash in a glass of water, and the same quantity of sulphate of magnesia (Epsom salt) in another, mix these transparent fluids together, which will immediately assume a milky appearance, filter the mixture, and a white powder will remain on the paper. In this case, to use a figurative expression, the acids change partners; the sulphuric acid going to the potash, to form a new compound, sulphate of potash, while the carbonic acid seizes the magnesia, forming carbonate of magnesia, which is *precipitated*, being insoluble in water.

The preceptor can easily convey an idea of this subject to the young mind, by the following diagram: connect two rods by their centres, as they stand in fig. 1; the sulphuric acid is supposed to be united with the magnesia, forming sulphate of magnesia, or Epsom salt; the carbonic acid is united with the potash: when the rods are moved, as in fig. 2, it will be evident that two new compounds are formed.

FIG. 1.

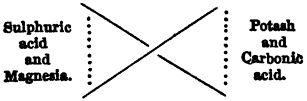
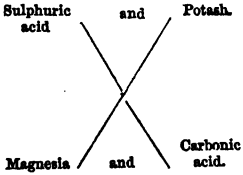


FIG. 2.



Many other illustrations can be given, by attaching new words.

### QUESTION.

58. What is implied by the term double decomposition, or compound attraction?

---

23. The third kind of chemical attraction receives the name of *disposing*, from the following circumstance (experiment 7): mix some olive oil with water in a phial, no combination takes place even by agitation, add some drops of caustic potash; a third body, which will cause the mixture to assume an homogeneous or uniform appearance, chemical union having ensued, the compound being termed soap. The attraction is termed disposing, as the third substance *disposes* two bodies to unite, which are otherwise hostile to each other, playing the part of a mediator, figuratively speaking.

### QUESTIONS.

59. When water, oil, and potash unite, why is the attraction termed disposing?

60. What is the difference between simple, compound, and disposing attraction?

---

## HEAT.

24. The next subject that comes under review is heat, one of the most powerful auxiliaries of the chemist: in most instances it is indispensable, for various bodies

may remain in contact, without chemical union, until the temperature is increased. It is by the agency of heat that the ores are forced to yield for our use the various metals; by heat man is enabled to forge the massive anchor; or from a preparation of the same metal, to form the watch-spring. By the term heat, strictly speaking, we understand the sensation produced by an agent named caloric, (Latin, *calor*, heat.) In general, however, we make no distinction between the cause and the effect.

We will not introduce here the various theories that have been advanced respecting the nature of heat; it is sufficient to point out to the young mind some of its remarkable effects. The sources from which we obtain heat are various, the sun being the universal one: we can also obtain inexhaustible supplies by *chemical* processes, as will be seen by the experiments noticed in these pages: occasionally, *mechanical* operations produce the same effect; this is admirably illustrated by friction. The production of heat by such means is known even to the uncivilized Indian, who lights his fire by rubbing two pieces of wood together. Axles of carriages are from the same cause frequently ignited; and in boring cannon, Count Rumford proved that so much heat is produced as to boil water. This was effected by surrounding the cylinder with water, preventing it from entering the bore by oiled leather. A very interesting fact connected with friction is seen in the whale fishery: after the giant of the deep receives the fatal harpoon, he plunges to a considerable depth, moving at the rate of eight or ten miles an hour, carrying with him the uncoiling rope from the boat. "Sometimes, however, to retard its motion, it is usual for the harpooner to cast one or more turns of the line round a kind of post, called the bollard, which is fixed near the stern of the boat for the purpose, and such is the friction of the line when running round the bollard, that it frequently envelopes the harpooner in smoke, and if the wood were not frequently wetted, it would set fire to the boat."—("Jardine's Naturalist's Library," one of the most interesting works of the day.) The development of heat by friction is also seen by the percussion of flint and steel. In this well-known operation, the particles of steel are so closely pressed together by the harder body, the flint, that sufficient heat is liberated to ignite minute particles of steel. Some erroneously suppose that the spark proceeds from the flint, Shakspeare entertained the same opinion.

"You carry anger as the flint bears fire,
Which much enforced, doth show a hasty spark,
And straight is cold again."

JULIUS CÆSAR.

In concluding the subject of friction, we may direct attention to *experiment* 8.—Melt one part of iron, with two of antimony, in a furnace; when cold, subject the mass, termed an alloy, to the action of a file, and brilliant sparks will be obtained.

### QUESTIONS.

**61. What is the scientific term for heat, with its derivation?**

**62. State some of the sources from which we obtain heat.**

**63. Give some illustrations of the disengagement of heat by friction.**

**64. When we strike steel against flint, does the spark proceed from the flint?**

**65. In this operation why do we obtain such heat?**

---

25. We have now to consider some of the general effects of heat, one of the most important being expansion.

*Experiment* 9.—Fit an iron cylinder accurately into an aperture made in sheet iron; when the cylinder is heated to redness, it will be found that it has become so much larger by the heat separating its particles from each other, the effect being termed expansion, that it will no longer pass through the aperture. If the heated metal be now plunged into water, it immediately returns to its original dimensions, the process being termed contraction.

The contraction and expansion of metals are frequently brought into operation in the arts: for example, in making large vessels for brewers, the iron hoops are made somewhat smaller than the circumference of the vessel; on being heated, they increase to such an extent, that they drop into their places, and by suddenly cooling them, the contraction that ensues binds the parts in the most forcible and uniform manner. By a similar contrivance, the wooden parts of carriage wheels are connected together, the iron hoop or tire being made smaller than the wooden circle.

Some idea can be formed of the enormous force with which metals contract on cooling, by the following circumstance:—two side walls of the *Conservatoire des Arts et Metiers,* a museum for models in Paris, having been pressed out by the weight of the floors, it was proposed by Monsieur Molard to save this national building by the laws to which we have just alluded. Several holes were made in the walls opposite to each other, through these strong iron bars were passed, heat was then applied to them in the apartment, circular plates having been previously screwed on the ends that projected outside of the walls, by the expansion of the bars they were lengthened; the circular plates were necessarily pushed farther from the walls, on being screwed up, the bars were cooled, contraction came into operation, and the yielding walls approached each other; by frequently repeating the same experiment, they were restored to their original position.

## QUESTIONS.

66. When we heated the iron cylinder, why did it no longer pass through the aperture?

67. How does contraction differ from expansion?

68. What use is made of this fact, in putting iron hoops on wheels and large vats?

69. Explain the process by which the museum for models in Paris was saved from falling.

26. The expansion and contraction of mercury enables us to ascertain with great precision the various temperatures of surrounding bodies. The instrument is termed thermometer, (Greek, θερμη, heat, μετρον, a measure:) it consists of a glass tube, terminated by a bulb, or hollow ball, filled with mercury, the opposite end being completely closed, by melting the tube over a flame, it is then said to be hermetically sealed. As the mercury expands by heat, it rises in the tube, and the abstraction of heat producing cold, causes it to fall; a scale is placed at the side, with the divisions termed degrees. The British thermometer, originally constructed by Fahrenheit, a Prussian, is marked or graduated from 0, termed zero, or nought, to 212 degrees, termed the boiling point, *at the level of the sea*, (*vide* 14.) Fahrenheit produced his zero by plunging the instrument in a mixture of snow and salt, which produces an intense degree of cold; he erroneously supposed that the cold produced by this frigorific mixture, (Latin, *frigor*, cold, and *facio*, to make,) was the greatest that man could obtain; this is not the fact; he therefore termed the starting point zero. At the 32nd division, or degree, he found that water was converted into ice, this he termed the freezing point; subsequently, placing it under the human tongue, the metal rose to 98 degrees, this is termed blood heat; about 76 degrees is summer heat in Great Britain; 60 degrees the medium. The next step was to apply heat artificially obtained: on plunging the thermometer in boiling water, the mercury continued to rise rapidly

until it reached 212 degrees, the boiling point, where it remained stationary. It is now necessary to explain why the mercury stops: having arrived at 212 degrees, heat so overcomes attraction of cohesion, (*vide* 13,) as to convert the water into an invisible body, termed steam. As steam occupies about 1728 times the space of the water from which it was produced, an increased quantity of heat must be absorbed, to keep it in this state; as it is entering into the composition of steam, it becomes *latent*, or concealed; in this condition, it makes no impression on the mercury; arriving, therefore, at 212 degrees, the succeeding supply of heat passes off with the atoms of water, to form steam.

### QUESTIONS.

70. What is the use of the thermometer? State its derivation.

71. How is it constructed?

72. Describe how Fahrenheit divided it?

73. Why does not the mercury pass 212° when the instrument is immersed in boiling water?

74. Why do we say 212° the boiling point at the level of the sea?

75. What is implied by the term latent heat?

---

27. The following experiments will prove that when a liquid is converted into vapour an increased portion of heat enters into its composition, or becomes latent:—

*Experiment* 10.—Pour some sulphuric ether, a very volatile fluid, upon the hand—it is immediately resolved into an invisible vapour, the process receiving the name of *evaporation;* at the same time, it will be found that an intense degree of cold will be produced: this arises from the heat of the blood being abstracted to become *latent* while entering into the composition of the ethereal vapour.

*Experiment* 11.—Drop sulphuric ether upon the bulb of the thermometer, previously covered with cotton; as it evaporates, the mercury can be made to sink below the freezing point. From these statements, it is easy to comprehend how damp clothes produce disease, by reducing the temperature of the surface of the body below the natural standard.

Upon this principle, apartments are kept cool in India, in the following manner:—Slaves are employed to sprinkle with water curtains suspended in the rooms; the rapid evaporation that ensues reduces the temperature within. The Arabs, while crossing their arid deserts, keep the water cool by covering the jars with linen cloths, which they occasionally moisten. According to Athenæus, the Egyptians employed the same process.

The porous earthenware vessels now used as wine coolers act upon this principle, the water imperceptibly evaporating at the external surface. The following suggestion may be found useful in domestic economy:—If we require a cold drink in summer, it can easily be obtained by rolling linen round the vessel, then leaving it immersed half way in water.

The upper portion of the linen will continue to absorb the fluid from below, while the heat of the atmosphere is producing rapid evaporation, and consequently the contents of the vessel will be cooled.

### QUESTIONS.

76. What is understood by the term evaporation?

77. When sulphuric ether is poured on the hand or the thermometer, why is the sensation cold produced?

78. How are the apartments in India kept cool?

79. Why are porous earthenware vessels used as wine-coolers?

---

28. Before we close the subject of the thermometer, it is necessary to state, that Fahrenheit's is used in the British dominions. In France they employ the thermometer constructed by Raumur and Celsius; the latter is termed the centigrade, as the number of divisions from the freezing to the boiling point are 100, (Latin, *centum*, a hundred, *gradus*, a degree.) A fourth kind, termed De L'Isle's, is used by the Russians. In an elementary work like the present it is advisable not to enter into a further description of these instruments. It is to be regretted that philosophers do not agree to employ only *one* of them in every country.

### QUESTIONS.

80. Why is the French thermometer termed centigrade?

81. Who constructed the thermometer used in Russia?

29. It should be particularly borne in mind that a few bodies *contract* by exposure to heat. This is particularly the case with pipe-clay and wood. This effect is produced by the expulsion of the watery particles causing the atoms of those bodies to approach each other more closely than in their natural condition. In slate quarries wedges are formed of baked wood; when these are driven into the rocks they absorb moisture, and the force produced by the wood returning to its original dimensions causes the *strata* to separate. Few persons who have not tried this experiment can form an adequate idea of the enormous pressure that can be thus summoned up by simply moistening baked wood.

### QUESTIONS.

**82. Do all bodies expand by heat?**

**83. Why do pipe-clay and wood contract by heat?**

**84. Describe the process by which slate rocks are sometimes split by wedges?**

---

30. We have shown that heat produces expansion with a few exceptions. We may now advert to the interesting fact, that there are some exceptions to the law that cold, which is merely the abstraction of heat, causes bodies to contract.

*Experiment* 12.—Pour some melted *bismuth*, a metal, into a bullet-mould; in cooling it will be found to have completely filled the cavity, showing that it expands in cooling. This is taken advantage of in making small type metal, which is composed of nine parts of lead, two of antimony, and one of bismuth; this mixture of metals, termed *an alloy*, expands in cooling; the mould is therefore entirely filled when the alloy is cold, and consequently no blemish is found in the letters. This constitutes a very important improvement in printing. Water is another remarkable exception to the law, as it expands in freezing; when its temperature is reduced to 32° Fahrenheit's thermometer, it becomes a solid, termed *ice;* the process is termed congelation; at this point, instead of descending to allow the warmer portions to ascend, it remains stationary, or, in other words, it floats. Few operations in nature show more evident proof of the benevolence of the Deity than this provision. If water had obeyed the general law in freezing, the ice in contracting would have sunk to the bottom, leaving another surface to be frozen; and thus, after some time, the ocean itself would have become a solid mass, entombing the myriads of its inhabitants, and the summer's heat of the succeeding year could not possibly have thawed it. Sometimes inconvenience and even danger to the individual, results from this exception—"partial evil, universal good." For example, water-pipes are burst by the freezing water; and even trees and rocks are torn asunder by water lodged in their crevices becoming ice. Floating icebergs constitute a formidable illustration of this danger.

*Experiment* 13.—*Fill* a phial with water in winter, and, having corked it, place it outside of the window exposed to frost—in the morning the glass will be found broken, and it will be seen that the ice is larger than the original water.

On one occasion, Major Williams tried the following experiment at Quebec:—Having fitted a plug weighing 3lb. into a bomb-shell filled with water, he exposed it to the action of the frost. The expansion of the contents in freezing projected the plug to a considerable distance; in screwing in the plug afterwards, the shell was actually burst. May we not, then, say, "Nature, nature, who can stop thy course!"

### QUESTIONS.

85. Do all bodies contract by cold?

86. Why is bismuth used in making small type-metal?

87. What design had the Creator in view in ordaining that water should expand in freezing?

88. When water freezes in pipes and crevices of rocks does it exert any force?

89. Describe the experiment which was tried in Quebec by Major Williams?

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31. It would be advisable to try the following (*experiment* 14) for the purpose of showing that water also expands by heat:—Pour water into an oil-flask* to within an inch of the top—on holding

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* Young persons who are desirous of performing experiments, should collect the empty oil-flasks at home, and have them washed with potash—they will be found extremely useful.

it over the fire the contents will overflow considerably below the boiling point. This experiment exhibited to a servant would show the necessity for not filling the kettle, as is usually done.

32. While the flask is in the hands of the operator it would not be a loss of time to try *experiment* 15. Boil a tea-spoonful of water in the flask—when full of *steam,* which occupies about 1728 times the space of the original *water,* invert it suddenly in a basin of cold water; the heat being abstracted from the confined steam, in returning to the state of water it *contracts* to its original dimensions, leaving a vacuum in the flask; the atmosphere then pressing on the water in the basin will force it up into the flask with considerable velocity, and in many cases will crack the flask. This experiment, presented accidentally to the gifted mind of Captain Savery, led him to construct the first steam-engine that was brought into operation in 1698.

### QUESTIONS.

90. You have said that water expands when frozen—does it also expand when heated?

91. To what extent does water expand when it is converted into steam?

92. When a flask filled with steam is suddenly immersed in cold water, why is it immediately filled from below?

---

33. We will close the subject of expansion and contraction by directing attention to *air,* which is also subject to this law.

*Experiment* 16.—Invert in water an oil-flask half filled with the liquid; pour hot water on the flask, when it will be found that the expansion of the confined air will expel the water. The converse of this is equally interesting. Having inverted the flask in water, pour some sulphuric ether over it; by its evaporation (*vide* exper. 10) the confined air will be robbed of a portion of its heat, and, contracting into a smaller space, will allow the atmospheric pressure to force the water into the flask. Upon the principle of air expanding and contracting, air thermometers are constructed.

*Experiment* 17.—Hold a light paper balloon over ignited spirit of wine; the heat will expel such a considerable portion of the air that the balloon will ascend from the following cause:—Heat is imponderable, that is, has no weight; when it expels *a part* of the air, a ponderable agent, the *remaining* portion, mixed with the heat, occupies the cavity of the balloon—and thus becoming lighter than an equal volume of the external atmosphere, it ascends upon the same principle that a cork floats in water.

### QUESTIONS.

**93. Give an illustration of the expansion and contraction of air?**

**94. When you ignite spirit of wine under a paper balloon, why does it ascend?**

34. We have now to consider the transmission of heat by *conduction*. It can easily be proved that heated bodies part with the overplus of the caloric to surrounding agents until a balance or equilibrium is established; but it has been wisely planned by the Creator that all substances should not have the same power of abstracting it from the heated bodies. On this account they are divided into *good* and *bad* conductors, the process being termed *conduction*. Solids possess this power in a greater degree than liquids or gases. Among solids, *metals* are the best. Among bad conductors we find glass, baked wood, charcoal, sand, hair, feathers, and fur. This can be made evident to a child, by holding rods of wood and iron over the flame of a lamp—the wood, while *red hot* at one end, can still be held by the other extremity; this will not be the case, however, with the iron—proving the unequal conducting powers of these bodies. A similar case will be seen in the construction of a teapot—the handle being a *bad* conductor of heat.

35. From a knowledge of these facts, we cannot fail to be struck with astonishment at the inimitable skill with which the Creator has protected animals. We have said that hair, feathers, and fur are among the worst conductors of heat: if, therefore, we cover a heated body with any of them, its temperature will be preserved from the external atmosphere; and it is worthy of observation, that in proportion as the climate is colder, the non-conducting cover is increased, as we see by comparing the few hairs on the elephant

### QUESTIONS.

102. Why are the eggs of the turtle hatched by being buried in sand?

103. Why do thick glass vessels split more easily by heat than thin ones?

104. Is water a non-conductor of heat?

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## THE ELEMENTS,

### OR SIMPLE BODIES OF WHICH OUR GLOBE IS COMPOSED.

39. When we look around us and behold the endless variety of nature's productions, it appears impossible, at a superficial glance, to ascertain the simple bodies or elements which enter into their compositions. By the unwearied exertions, however, of the human mind, we are led to suppose that about fifty-five elements were employed by nature in constructing the animal, vegetable, and mineral kingdoms. This is at present the received opinion; subsequent discoveries may prove that they are more or less. The ancients supposed that the elements of nature were fire, air, earth, and water: modern chemistry proves that the three latter are *compound* bodies; of the real nature of fire or caloric nothing as yet has been determined. We find traces of the ancient opinion in poetry and general conversation. Thus

we usually say during a storm that the *elements* are raging; or,

> "As yet amid this *elemental* war
> That scatters desolation from afar,
> Nor toil, nor hazard, nor distress appear,
> To sink the seaman with unmanly fear."
>
> —*Falconer's Shipwreck.*

Before we consider the properties of some of the elements, it is necessary to state that no natural or artificial operations cause their destruction. Chemistry enables us, it is true, to decompose compounds presented to us by nature, and from their compound parts to form new combinations. This we can repeat at pleasure, but the elementary bodies which we have thus sported with remain uninjured. This is one of the most certain facts with which man is acquainted.

### QUESTIONS.

105. What is an element?

106. Were the ancients correct in calling fire, air, earth, and water elements of nature?

107. How many elements are we acquainted with?

108. Are the elements ever destroyed during natural or artificial operations?

## LIST OF ELEMENTS.

*Those marked (*) will be particularly noticed in the following pages :—*

1. *Oxygen.
2. *Hydrogen.
3. *Nitrogen.
4. *Chlorine.
5. *Carbon.
6. *Sulphur.
7. *Phosphorus.
8. *Iodine.
9. *Bromine.
10. Fluorine.
11. Selenium.
12. Boron.
13. *Silicium.
14. *Aluminum.
15. *Magnesium.
16. Yttrium.
17. Zirconium.
18. Thorium.
19. *Potassium.
20. *Sodium.
21. Lithium.
22. *Calcium.
23. *Barium.
24. Strontium.
25. *Gold.
26. *Silver.
27. *Platinum.
28. *Mercury.
29. *Copper.
30. *Iron.
31. *Lead.
32. *Tin.
33. *Zinc.
34. *Antimony.
35. *Arsenic.
36. *Cobalt.
37. *Manganese.
38. *Bismuth.
39. *Chromium.
40. Tellurium.
41. Titanium.
42. Cerium.
43. Glucinum.
44. Tungsten.
45. Vanadium.
46. Molybdenum.
47. Cadmium.
48. Palladium.
49. Rhodium.
50. Iridium.
51. Osmium.
52. *Nickel.
53. Uranium.
54. Lanthanum.
55. Tantalum.

## OXYGEN.

40. This is one of the most important and universal agents of nature. In an uncombined or free state it is a gas : this term is applied to those bodies that do not become solid or liquid *at the ordinary temperature of our atmosphere.* Oxygen forms about a fifth part of our atmosphere, eight parts in every nine of water,

an immense portion of our solid globe, and enters into the composition of every animal and vegetable. Taking this view of the case, there is no mind that can investigate this subject without feelings of peculiar interest. The term oxygen is derived from the Greek (*οξυς*, acid, and *γενναω*, to create), as it was supposed by Lavoisier that it was the sole cause of the formation of acids: subsequent discoveries have proved that this opinion was false—the term, however, is still retained. It was discovered by Dr. Priestley in 1774.

41. It can be obtained from various sources, from which we select the following:—

*Experiment* 18.—Put one or two ounces of black oxide of manganese, a compound of oxygen and manganese, into a small glass or earthenware retort, (fig. 3,) with about an equal weight of sulphuric acid

FIG. 4.

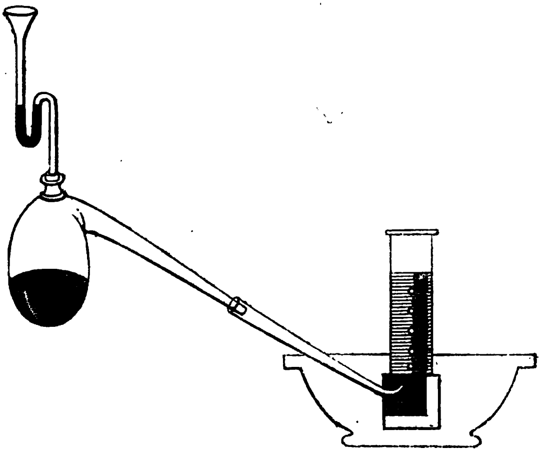
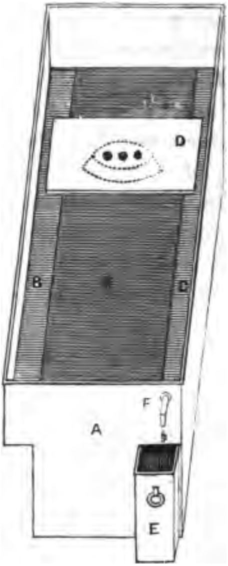


FIG. 3.

FIG. 1.

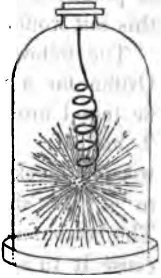
(vitriol). On applying the heat of a lamp, the sulphuric acid will seize the metal manganese, and liberate the greater portion of the oxygen, which can be collected in inverted glass vessels placed on the shelf of the pneumatic trough—(so termed from πνευμα, air or gas, as it is only used for collecting gases.) A little practice will enable a young person to use it.—(*Vide* fig. 9.) The wood-cut represents a tin pneumatic trough of Griffin — convenient dimensions are, thirteen inches long, seven wide, and four deep. The shelf B is one inch wide, and C three inches. At the end there is a pipe, F, half an inch from the top, that carries off the water as it flows from the various jars during the operation of filling them with gas — the sliding vessel E receives this discharged water. The shelf D, perforated in the centre, moves along B and C; the dotted lines represent a tin vessel soldered beneath, to prevent any gas from being lost as it passes from the retort, the beak of which is placed under it. To collect gas by this apparatus, a glass jar is filled with water, and inverted, as in fig. 5,

FIG. 9.



upon the moveable shelf D (fig. 9.) As the gas enters the water is displaced, and flows through F into E. The jars, when filled with gas, may be left on the fixed shelf C, or removed with their mouths in trays containing water, as in fig. 5. The earthenware chemical apparatus, constructed by Mr. Griffin of Glasgow, is admirably adapted for beginners; the expense is very trifling. The safety-tube, fig. 4, made of glass, should be attached to the retort—its principal use is, to prevent the external atmosphere pressing on the water in the basin or pneumatic trough from forcing a portion of cold water into the heated retort when a vacuum would be formed by the removal of the lamp (examine carefully exper. 15.) The safety-tube is about sixteen inches long, bent as in the figure—the dotted lines represent water. When a vacuum is formed, the air rushes through the tube into the retort, forcing a passage through this small portion of water.

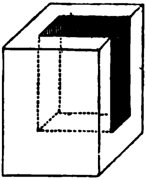
FIG. 5.



*Experiment* 19.—We can procure a considerable quantity of oxygen by using the black oxide of manganese alone—in this case a greater heat must be employed. Instead of a glass retort, a cast-iron bottle is employed with a small iron tube ground into it: the other extremity dips into the pneumatic trough. As the heat of a lamp is insufficient, the vessel must be placed in the fire. An old gun-barrel, having the touch-hole closed, is an excellent substitute for the iron bottle. The joints should be covered with a paste or lute composed of fire-clay.

*Experiment* 20.—Oxygen of a very pure description can be obtained by heating a small quantity of chlorate of potash in a glass retort—for general experiments this salt would be found expensive.

FIG. 2.



The following cheap substitute of Griffin for a pneumatic trough will be found interesting.—(*Vide* fig. 1, 2, and 3.) Figure 2 represents a wooden block with an opening cut in it, as shown in the sketch. The bottom is plugged with lead to cause it to sink in water. Fig. 1 shows the manner in which it is placed in a basin of water. When a long glass vessel, termed a jar, is to be filled with a gas, place it full of water, in an inverted position, over the hole cut in the block; when the beak of the retort (fig. 3) is placed in the opening, the gas issuing from the retort enters into the jar and displaces the column of water. In the absence of a pneumatic trough, this arrangement will answer for young persons.

## QUESTIONS.

109. What is understood by the term gas?

110. Is oxygen gas employed by nature as an universal agent?

111. What is the derivation of the term?

112. By whom was it discovered?

113. Is oxygen which signifies acid-maker strictly correct?

114. When we pour sulphuric acid on black oxide of manganese and apply heat, why do we obtain oxygen?

115. How can we obtain oxygen from the oxide of manganese without sulphuric acid?

116. What is the derivation of the term pneumatic?

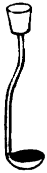
117. Describe the general principle upon which a pneumatic trough is made?

---

42. In a pure state, oxygen is devoid of colour, taste, or smell—it can, however, be easily distinguished from any other gas by the following properties:—

*Experiment* 21.—Having carefully removed one of the jars (fig. 5) from the shelf of the pneumatic trough, with its mouth immersed in a tray of water, suspend in the oxygen a piece of *lighted* charcoal; it will immediately burst into a splendid flame. A similar effect is produced upon a coil of *red* hot iron wire, or a taper that has been just extinguished, the wick *still* remaining red.

FIG. 6.



*Experiment* 22.—A piece of *ignited* phosphorus, placed in fig. 6, burns with so intense a flame in oxygen that the eye can scarcely bear its brilliancy. This is *a dangerous experiment;* in fact, any experiments with phosphorus should be carefully performed by young persons, as this extraordinary element ignites by the heat of the hand, and produces a more dreadful burn than red hot iron. It cannot be sufficiently impressed upon the memory that it should be cut under water, when required, into pieces not exceeding the size of a pea, which should be removed with a pointed wire.

*Experiment* 23.—If a glow-worm be placed in oxygen in a dark room, it moves with increased exertion, and its lamp burns with a brighter flame.

The compounds formed by phosphorus, &c., with oxygen, alluded to in the preceding experiments, are divided into *acids* and *oxides*. The phosphorus becomes an acid, so does the charcoal (*vide* carbonic acid); the iron wire, on the contrary, is converted into the *oxide* of iron, popularly termed rust; the iron, under such circumstances, is said to be *oxidized*. The process is termed *oxidation*. Sometimes this oxidation takes place slowly, and without any appearance of heat or light, as is seen in the rusting of iron and the majority of the metals, when exposed to the action of the atmosphere. In these cases the metallic lustre is invariably destroyed—particularly if the metal have been melted: some fine metallic colours, red lead, cobalt blue, &c., are prepared in this way.

43. The ordinary combustion of inflammable bodies is nothing more than the consumption of oxygen derived from the surrounding air, a fifth of which is oxygen. This will be more fully explained presently.

The most important portion of the subject is the part which the oxygen of the air plays in the animal economy, it being the principle that supports life, as will be explained when we treat of *carbonic acid*. The next gas for consideration is nitrogen, that forms the greater part of the atmosphere.

### QUESTIONS.

118. When a piece of lighted charcoal is suspended in oxygen, what peculiar effect is produced?

119. Does red hot iron wire burn in oxygen?

120. Does ignited phosphorus burn in this gas?

121. Is a glow-worm affected by it?

122. What two great classes of compounds are formed by oxygen uniting with other bodies?

123. When charcoal burns in oxygen, what is formed?

124. What does iron form under similar circumstances?

125. Does oxidation, which signifies the absorption of oxygen, take place in the atmosphere?

126. In the combustion of coal, candles, &c., is this gas actively engaged?

127. What proportion of our atmosphere does oxygen form?

128. Is it instrumental in supporting life?

## NITROGEN.

44. This gas is so termed, because it enters into the composition of nitre. It was formerly termed azote (from α, the Greek negative, and ζωή, life), because it destroys life. This title was objectionable, as there are many other destructive agents. Nitrogen is lighter than air, and forms four-fifths of the volume of our atmosphere; the remaining fifth is oxygen. It is found in all animal substances, and seems to promote vegetation in a considerable degree, as it is invariably found to form a considerable portion of those parts of plants which perform the most impor-

tant offices. Its principal use in the atmosphere is to dilute it, which, if composed of oxygen alone, would consume inflammable bodies with too much brilliancy. Life, also, would have been of momentary duration without the nitrogen, as has been proved by placing a small animal in oxygen. Its first effect is to stimulate—this is attended by laborious and hurried breathing, followed by the death of the animal before all the oxygen is consumed. It is particularly worthy of notice, that if we *nearly* reverse the proportions of oxygen and nitrogen which form our atmosphere, we will form an acid termed nitrous, or aquafortis.

100 parts of air are composed of 79 nitrogen, 21 oxygen.
100 parts of nitrous acid, 25 nitrogen, 75 oxygen.

This alone gives us a strong proof of how much we owe to the Creator, without whose special superintendence the proportions of these gases might be reversed—then animals and plants would perish from the withering influence of the acid fumes.

*Experiment* 24.—By the following simple process we obtain nitrogen sufficiently pure for general purposes:—Ignite a piece of phosphorus, the size of a pea, on a small stand under a glass jar divided into five parts, with its mouth immersed in two or three inches of water. As the phosphorus burns it consumes the oxygen of the confined air, forming white acid fumes, which in a few minutes will be absorbed by the water leaving the nitrogen within. The space that had been occupied by the oxygen will be taken by the water from below, and as it rises as high as one of the five divisions, it will give a good idea of the proportion of oxygen in the atmosphere being one-fifth. This is the most simple but not the most accurate process.

*Experiment* 25.—If we take a jar of nitrogen from the pneumatic trough, and quickly place it, while inverted, over a lighted candle, it will be extinguished. This proves two points—that it is lighter than air, and destroys flame.

*Experiment* 26.—It may be interesting to prepare artificial atmospheric air, by introducing one-fifth of oxygen into the jar of nitrogen prepared by exper. 24. When the oxygen displaces the water, the two gases should be mixed by agitation, when it will be seen, by plunging a lighted taper or a mouse into the mixture, that it resembles air.

### QUESTIONS.

129. Why is nitrogen so termed?

130. Is it objectionable to call it azote?

131. By what experiment will you prove that it is lighter than air?

132. What is it mixed with to form air?

133. What proportion of the atmosphere does it form?

134. Is it found in animal substances?

135. As it destroys life, what is its use in the atmosphere?

136. If we reverse the proportions of nitrogen and oxygen, what will result?

137. Describe the experiment by which we can obtain nitrogen?

138. How can we prepare artificial atmospheric air?

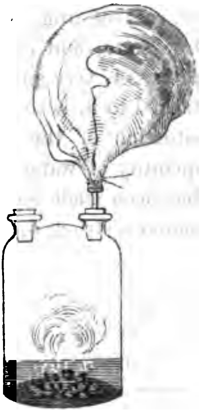
## HYDROGEN.

45. This elementary body plays a most important part in the economy of nature, and therefore must be particularly considered. The term is derived from the Greek *υδωρ*, water, and *γενναω*, to form, because it enters into the composition of water. This term was given by Mr. Cavendish, by whom its properties were first accurately described. It can *only* be obtained in its free state from water, the composition of which is—

| | | |
|---|---|---|
| By weight, | Hydrogen, | 8 parts. |
| „ | Oxygen, | 1 part. |
| | | 9 water. |
| By measure or volume, | Hydrogen, | 2 parts. |
| „ | Oxygen, | 1 part. |
| | | 3 water. |

This gas is found nearly in all animal and vegetable substances: it is *exceedingly* inflammable, but extinguishes flame; it is also destructive to life; it is the lightest of all known bodies. Some idea of its levity can be formed from the fact, that it is nearly fourteen and a half times lighter than air. In consequence of this property, it was originally employed for inflating balloons. It may not be uninteresting to state that Montgolfier of France first exhibited the ascent of a large balloon inflated by heated air, in 1783: Pilatre de Rozier was the aeronaut. In December of the same year, Messrs. Charles and Roberts ascended from Paris in the first balloon inflated with hydrogen. Pilatre de Rozier then tried a balloon with heated air placed below one containing hydrogen, which, taking fire at a considerable height, produced a fatal result. In the present day, coal gas, which will be considered in the article carbon, is used instead of hydrogen. This substitute was first proposed by Mr. Green. Some idea of the difference in expense may be formed from this statement—Mr. Green's balloon can be inflated with coal gas for twenty pounds; a sufficient quantity of hydrogen would cost one hundred.

FIG. 8.



*Experiment* 27. The process by which we obtain this inflammable gas from water is very simple: having made a mixture of two drachms of sulphuric acid, (vitriol,) and one ounce of water, in a gas bottle (fig. 8,) add some iron filings, recently prepared,* a violent action will instantly commence, arising from the iron separating the oxygen from the water; the compound of iron and oxygen, termed oxide of iron, is then seized by the sulphuric acid, to form a salt, termed sulphate of iron; the hydrogen being liberated, escapes in the state of gas, and can be collected in the pneumatic trough, a small balloon, or bladder. This was the original process for inflating balloons.

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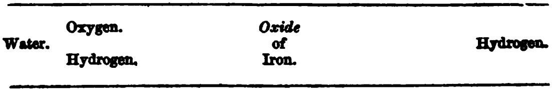
* They can always be had at the bench of the ironmonger.

*The pupil is earnestly requested never to apply a lighted taper to the bottle in which the hydrogen is generated; serious accidents sometimes arising from a portion of air, originally in the vessel, being mixed with it, forming an explosive mixture. If the hydrogen be collected in a bladder, or pneumatic trough, the following experiments can be performed with perfect safety.* (*Vide experiment* 33.)

*Experiment* 28.—By passing a current of steam through a red hot iron tube, we can also obtain hydrogen. This arises from the heated iron decomposing the water; that is, it seizes the oxygen to form oxide, or rust of iron, when the hydrogen passes on in a free state, and can be collected for experiment; the process is very simple: a tube, with a stop-cock attached to it, is to be soldered to a gun-barrel, in the situation of the touch-hole, through this a small quantity of water can be poured when the gun-barrel has been made red hot in the middle, by being laid across a strong fire.

Red-hot Iron Tube.



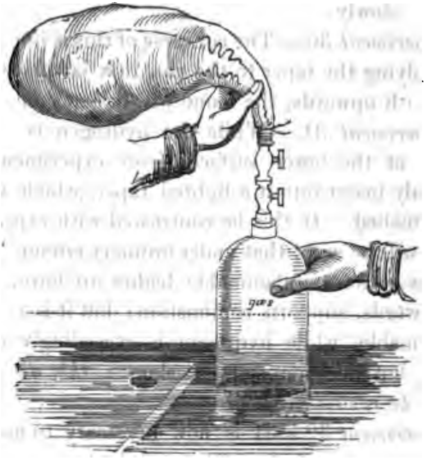
*Experiment* 29.—Fill two or three long jars with hydrogen, by performing experiment 27; remove one of them in its *inverted* position, and apply a lighted taper; the gas will instantly take fire, but it will be observed that it burns slowly; this arises from its levity causing it to remain in the vessel, and consequently, as the oxygen of the external air can only be supplied at the lower surface, the combustion must proceed slowly.

*Experiment* 30.—The converse of this is important: on applying the taper to the gas, in a jar placed with its mouth upwards, the flame will be but momentary.

*Experiment* 31.—While the hydrogen is burning slowly at the lower surface, (*vide* experiment 29,) suddenly insert into it a lighted taper, which will be extinguished. If this be contrasted with experiment 21, it will be seen, that under ordinary circumstances, oxygen enables inflammable bodies to burn, or, in other words, supports combustion; but it is not itself inflammable, while hydrogen is exceedingly inflammable, but does not support flame: *this distinction should be remembered.*

*Experiment* 32.—It is now necessary to ascertain what becomes of the consumed hydrogen, for we know that it is not destroyed, (*vide* question 108.) The following experiment will prove, that as it burns, it unites with one volume of oxygen, to form water: attach a stop-cock and nozzle to a bladder, then having filled it with hydrogen, ignite it, and hold over the flame a *large dry* glass vessel, in a few moments water will be seen, in the form of vapour, upon the inside of the inverted vessel. The proper method of filling a bladder with gas, is to moisten it, and expel the contained air, by pressing the sides together, while the operator attaches it to the gas bottle, (fig. 8,) or the jar for the pneumatic shelf, (*vide* fig. 7.) From this statement the pupil will easily understand why a bent tube, terminating in a hollow glass ball, is placed over gas lamps in shops; the watery vapour produced by the union of the hydrogen of the coal gas with the oxygen of the air being cooled in the bent tube, is collected in the ball. Familiar facts like these should always be explained to youth by their preceptors.

FIG. 7.



*Experiment* 33.—While hydrogen unites with oxygen to form water, a violent and sudden action takes place, which can be proved by mixing one measure of oxygen with two of hydrogen in a *bladder; any other vessel should be avoided*. After a slight agitation, pierce the bladder with a pointed instrument, and apply a lighted taper; a very loud explosion will ensue, with the destruction of the bladder. If it be attached to a wall, no accident *can possibly occur*, otherwise it would not be noticed in these pages. From this fact it will be understood why it is dangerous to apply a lighted taper to the bottle in which hydrogen is generated: a portion of air may be mixed with it, and the explosion follows; the glass vessel will generally be broken. *It is hoped that this caution will never be forgotten.* The fire-damp of coal mines results from a similar cause.

*Experiment* 34.—Attach a smoking-pipe to the gas bottle, having placed some soap lather in the bowl; bubbles, called soap balloons, will be formed, which, by a little dexterity, can be detached; these will rapidly ascend; or procure at the toy-shop a French balloon, made of animal membrane, which will ascend when inflated.

*Experiment* 35.—The following is a beautiful illustration of the affinity or attraction which hydrogen has for oxygen:—dissolve a few grains of nitrate of silver, (lunar caustic,) composed of *oxygen*, nitric acid and silver, in distilled water, moisten silk or paper with the solution, and hold it closely over the bottle from which hydrogen is escaping, in a few moments it will be seen that a metallic coat of silver is exposed, resulting from the hydrogen having removed the oxygen from the salt of silver, or deoxidised it, causing the liberation of the *silver*, which is not soluble in the *nitric acid* without the *oxygen*. When the student commences the study of galvanism, he will find that on this beautiful principle are founded Daniell's battery, the electrotype, &c.

In concluding the article on hydrogen, it is necessary to state, that it is extensively used with oxygen in the proportions to form water, in the *oxy-hydrogen blow-pipe*, and *oxy-hydrogen microscope*: in the first, to obtain such an intense heat as to melt the most refractory bodies; and in the second, to procure a light, with the assistance of lime, which is intolerable to the eye. In using these instruments the gases are kept in separate vessels; by pressure the two streams are sent into a single chamber, lying behind the nozzle: by this arrangement no accident can possibly occur.

## QUESTIONS.

139. What is the derivation of the term hydrogen?

140. Who proposed it?

141. From what can it be obtained?

142. What is the composition of water by volume and weight?

143. How many times lighter than air is hydrogen?

144. Who first ascended in a balloon in the year 1783?

145. Are balloons inflated with pure hydrogen in the present day?

146. On pouring some iron filings into a mixture of sulphuric acid and water, why is the hydrogen liberated from the water?

**147.** Can you explain why it is dangerous to apply a lighted taper to the gas-bottle?

**148.** When steam passes through a *red hot* iron tube, why does hydrogen make its appearance at the other extremity?

**149.** When you apply a lighted taper to hydrogen, with the mouth of the vessel downwards, why does it burn so slowly?

**150.** Would it burn without the oxygen of the surrounding air?

**151.** Why does it burn so rapidly when the vessel is not inverted?

**152.** Does a lighted taper burn in hydrogen?

**153.** Would an animal live in the same situation?

**154.** What alone supports life?

**155.** Describe a marked distinction that exists between oxygen and hydrogen with respect to inflammability?

**156.** While hydrogen is burning what is formed?

**157.** If we ignite the gases mixed in a bladder, does any peculiar effect take place at the moment the water is formed?

**158.** Explain why silver is liberated when a current of hydrogen acts upon nitrate of silver.

## CHLORINE.

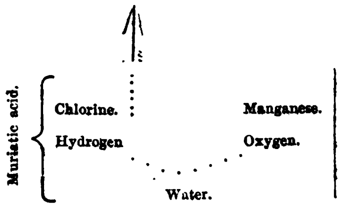
46. This important element was discovered by the celebrated chemist, Sir Humphrey Davy. From its greenish colour he proposed to call it chlorine, from the Greek χλωρὸς, green. It is heavier than the atmosphere, possesses a most suffocating and pungent odour, is destructive to life, acts powerfully on metals, and *partially* supports combustion. Its most important properties are, that it destroys vegetable and animal colours, and neutralizes the effects of the

effluvia which escapes from decomposing animal and vegetable bodies; it is therefore extensively employed as a bleaching and disinfecting agent.

*Experiment* 36.—By the following process, we disengage chlorine in sufficient quantity for experiments:—heat cautiously in a retort, a mixture of one ounce of black oxide of manganese, and three ounces of muriatic acid, (*a combination of hydrogen and chlorine,*) the liberated chlorine is collected in the *pneumatic* trough like the other gases, with this exception, that *warm* water must be used in the trough, as the chlorine is absorbed by cold: the operator is carefully to avoid breathing the gas, as it exerts, even in small quantities, a more injurious effect upon the lungs than other noxious gases, hydrogen, &c.: a free current of air should pass through the room in which the operation is performed.

47.—The explanation, termed in chemistry *rationale*, of the preceding process, can easily be understood, even by a young student, (fig. 11.) On mixing muriatic acid, *which is composed of chlorine and hydrogen*, with black oxide of manganese, *composed of*

FIG. 11.



*an excess of oxygen and the metal manganese,* one part of the muriatic acid is decomposed, its chlorine passes to the pneumatic trough, while its hydrogen seizes a portion of the oxygen from the manganese, to form water. (*Vide* experiment 32.)

*Experiment* 37.—If we require a small quantity of chlorine quickly, it can be obtained by pouring a spoonful of muriatic acid upon the same quantity of *chloride* of lime, composed of *chlorine* and lime; the muriatic acid, by superior affinity, unites with the lime, while the chlorine seeks its liberty; this is not sufficiently pure for some of the following experiments:—

*Experiment* 38.—From the articles on oxygen and hydrogen, it will be seen, that when we burn a taper in common air, the oxygen of the latter is seized by the hydrogen and carbon of the taper, to form water and carbonic acid: if, on the contrary, we suspend a lighted taper in chlorine, it is *only* its *hydrogen* that burns, while the *carbon* passes off, forming a dense black smoke: in this operation the hydrogen unites with the chlorine, to form muriatic acid, (*vide* experiment 36:) as it burns it will remind us of the appearance of the sun during a dense fog.

*Experiments* 36 and 38 illustrate in a very remarkable manner the important operations in chemistry termed *analysis* and *synthesis*—the first, (derivation Greek, *αναλυω*, to loosen,) is resolving a body into its constituent parts. In experiment 36 we found muriatic acid to be composed of *chlorine* and *hydrogen:* in experiment 38, a case of *synthesis*, (derivation

Greek, συντιθημι, to compose,) we formed a compound muriatic acid which we had previously analysed.

48.—When speaking of oxygen, it was stated that it did not invariably form acid, (*vide* 40,) as Lavoisier supposed: experiment 38 forcibly corroborates this statement; the advanced student will find many other instances.

*Experiment* 39.—It will be important to prove that chlorine affects colours, thus constituting a bleaching agent: suspend some pieces of moistened linen cloth, *variously* coloured, in chlorine gas, they will be bleached immediately, if they have been dyed with vegetable or animal colours; the object of *moistening* the cloth is to allow the *chlorine* to *decompose* the water, thus forming *muriatic* acid by abstracting its *hydrogen:* that such an effect is produced is evident, from the fact that *dry* colours are not affected.

*Experiment* 40.—Suspend a *moistened* engraving, *stained with ink*, in *chlorine*, the engraving comes out uninjured, while the ink disappears. *In consequence of this property of chlorine, it has been employed by dishonest persons for erasing names and sums of money out of wills;* this fact should be known to every member of society: a simple preventive is, to use, on such important occasions, *indestructible inks;* many have been recommended; the following is easily prepared:—mix fine lamp-black with sulphate of indigo (indigo dissolved in sulphuric acid, which can be procured at the dyer's); this mixture is not affected by chlorine.

*Experiment* 41.—It is advisable, while investigating this subject, to illustrate the use of *mordants* in dyeing, (derivation Latin, *mordeo*, to take hold,) which serve to *fix* colours: paint with muriate of tin any characters on cloth, dyed with vegetable blue, no apparent change is produced till it is immersed in *chlorine*, then the characters remain of the original blue, while the ground-work will be bleached.

*Experiment* 42.—It was stated (46,) that chlorine acted powerfully on metals; this is easily proved, by suspending in it silver leaf, which takes fire, producing a *chloride* of the metal; this is the case with many other substances.

*Experiment* 43.—By exposing quick-lime in powder to its action we form *chloride of lime*, which is so extensively used as a disinfecting agent, as follows:—mix the chloride with water, then add a teaspoonful of muriatic acid occasionally during the day, small portions of chlorine are consequently liberated. (*Vide* experiment 37.) Its action in this case seems to be, to neutralize the effect of noxious vapours: on such occasions it is advisable not to add more than a teaspoonful of muriatic acid each time, as chlorine, in a concentrated state, is calculated to injure delicate lungs. To prevent accidents families should use *chlorine water*, to be purchased at the druggist's. The pupil can imitate the process by using *cold water* in the pneumatic trough. (*Vide* experiment 36.)

Among the acids in second part, will be noticed muriatic, the chloric, and chlorate of potash, very important subjects connected with chlorine.

## QUESTIONS.

159. Who discovered chlorine?

160. Why was it so termed?

161. Is it lighter or heavier than the atmosphere?

162. Does it support life and combustion?

163. What effect has it on vegetable and animal colours?

164. Why is it called a disinfecting agent?

165. When we mix muriatic acid with black oxide of manganese to form chlorine, what are the proportions?

166. Why is it necessary to use warm water in the pneumatic trough?

167. Is any precaution necessary while we are liberating the gas?

168. Can you explain why chlorine is liberated by the process?

169. When this gas is united with lime, what is the compound termed?

170. How can we separate the chlorine from the chloride of lime, to use it as a disinfecting agent?

171. You have seen that chlorine partially supports combustion, when the lighted taper was in it what caused the dense smoke?

172. What acid was formed by the union of chlorine and hydrogen?

173. What is the difference between analysis and synthesis?

174. When we suspend coloured cloth in chlorine to bleach it, why is it essential that it should be moistened?

175. As common ink is removed by this gas, what should be used for writing wills, &c.

176. Describe the experiment with muriate of tin, to illustrate the use of mordants in dyeing.

177. Are thin metallic leaves affected by chlorine?

178. How can we form chlorine water?

## IODINE.

49.—This extraordinary element was accidentally discovered in 1812, by Monsieur de Courtois, of Paris, while procuring soda from sea-weed. It is a very volatile solid of a brownish-black colour; when *slightly* heated it becomes a violet-coloured vapour, from which it assumes its name (Greek, *ιωδες*, like a violet). It has a peculiarly acrid taste, and is a deadly poison: when rubbed to the skin it leaves a brown stain; it is only partially soluble in water, 7000 parts being required to dissolve one; it is very soluble in spirits of wine, forming tincture of iodine; an important use made of it in the present day is to reduce glandular swellings; it is also employed in the Daguerreotype, the process by which the most accurate representations of nature are traced by light.

*Experiment* 44.—Heat a particle of iodine in a flask, it instantly fills the cavity with the characteristic vapour.

*Experiment* 45.—If we wish to detect *starch* in the smallest quantity in a fluid, we have but to add a few drops of the solution of iodine; if the mixture assume a purplish tinge, we pronounce that starch is present; or by starch we detect iodine.

*Experiment* 46.—When iodine unites with mercury, we are presented with a splendid pigment: mix the *colourless* solution of iodide of potassium, (commonly called hydriodate of potash,) which contains iodine, with a *colourless* solution of corrosive sublimate, a preparation of mercury and chlorine, a *pre-*

*cipitate* of a brilliant red colour (the iodide of mercury) is instantly produced: this can be collected by pouring the mixture on filtering paper, the iodide of mercury remaining behind: the pupil is recommended to acquire the habit of thus separating precipitates.

50.—In concluding the article on iodine, it is advisable to state, that when it combines with a substance *below* it, the gas *chlorine*, for example, the compound is termed the *chloride of iodine;* but when with bodies *above* it, such as *potassium*, or *mercury*, we style the compound the *iodide* of potassium, or *mercury*.

## QUESTIONS.

179. When was iodine discovered?

180. What is the difference in colour between iodine when solid and in the state of vapour?

181. What is the derivation of the term?

182. Does it affect the skin?

183. In what proportion is it soluble in water?

184. What is tincture of iodine?

185. Describe the experiment by which the vapour of iodine was exhibited.

186. Explain how starch is detected by iodine.

187. What do we understand by the term iodide?

188. When iodine is mixed with chlorine, why do we say chloride of iodine, and not iodide of chlorine?

## BROMINE.

51.—This new element is generally obtained from the residual liquor procured at the salt-works after the separation of the table-salt from sea-water. In an elementary work like the present, it is not necessary to describe the process, which is rather complicated. Its term is derived from the Greek, (*βρωμος, fætor,)* in consequence of its possessing a most disagreeable odour. When viewed by reflected light it has a blackish-red colour, but by transmitted light it presents a hyacinth red. This extraordinary element is volatile, has a remarkably strong taste, and acts powerfully on the metals and other bodies forming *bromides:* one of these, the *bromide of silver,* is almost instantaneously darkened by exposure to light, on which account it is extensively used in the inimitable process of the Daguerreotype, so called from the celebrated inventor, Daguerre, of Paris. A brief outline of this subject will be given in the third part of this work, in the article on silver.

### QUESTIONS.

189. Why is bromine so called?
190. From what is it obtained?
191. What is its colour?
192. When united with silver, what is the compound called?
193. What property of the bromide of silver renders it so useful in the Daguerreotype?

## SULPHUR.

52. This useful and extraordinary agent seems to be universally scattered over the globe—sometimes in its *simple* or *elementary* state, as in volcanic countries, but generally in combination with other bodies. It is a solid of a pale, yellow colour, nearly insoluble in water, exceedingly brittle, and possessing but little taste or smell. It melts at the temperature of 226 Fahrenheit's thermometer. By increasing the heat it passes off in the state of vapour, which, meeting with a cold surface, is condensed into a fine yellow powder, termed sublimed sulphur, or flowers of sulphur.

*Experiment* 47.—Heat a spoonful of sulphur in a crucible; arrest the vapour by holding over it an inverted cup, kept cool. This illustrates, in a pleasing way, the process by which sulphur is obtained from the sulphurous grounds in Italy, and from the ores of the metals, copper, lead, and iron, in Great Britain and other countries. This process is termed by miners *roasting;* when thus united, either naturally or artificially, with the metals, the compounds are termed *sulphurets*. It may not be uninteresting to state here, that the county of Wicklow, in Ireland, is vieing with Sicily in the manufacture of sulphur.

*Experiment* 48.—To prove that such is the composition of a *sulphuret,* we have but to apply a piece of roll sulphur, termed popularly cane brimstone, to the end of a bar of iron heated to whiteness at a smith's forge. The sulphur unites with the iron, and the resulting compound, termed sulphuret of iron, falls down, and can be collected.

53. Sulphur is extracted from the minerals containing it in Sicily by the following process:—Ten earthen pots, a yard high, containing about four gallons, are ranged in a furnace called the gallery; the pots are so arranged that they partly project outside of the walls, while their tops rise above the roof. When filled with lumps of the sulphur ore, they are covered with earthenware lids; from the shoulder of each vessel a pipe two inches in diameter bends down and enters another covered vessel perforated at the bottom, standing over a tub filled with water. On applying heat to the gallery the sulphur melts, passes over in the state of vapour, and runs down in a liquid state into the water, where it congeals. As the lids are above the roof of the gallery, they can be re-charged when required. In 1839, Sicily produced 70,000 tons of sulphur, and Tuscany 1200, of which Great Britain consumed 46,000. Sulphur has been known for ages. In the present day it is extensively employed; as it ignites at a moderate temperature, it is used for matches; and in consequence of its fumes, when burning, affecting certain colours, is employed to bleach woollen and silken goods. (*Vide* exper. 49.) As these fumes (consisting of sulphur and oxygen of the air, termed sulphurous acid) will not support flame under ordinary circumstances, a handful is sometimes thrown

on a fire to extinguish it when danger is apprehended by soot being ignited in the chimney. Sulphur possesses the singular property of checking fermentation in wine vats, without injuring the wine. It is an excellent medium for taking impressions from seals. (*Vide* exper. 48.) Its principal uses are, for the manufacture of vermillion or cinnabar, gunpowder, sulphuric acid, or vitriol, and some important medicines.

*Experiment* 48.—Melt some sulphur in a clean ladle; keep it for some minutes in that state, and pour it on medals surrounded with circles of card; the impressions generally are beautiful.

*Experiment* 49.—To illustrate its bleaching property, suspend a red rose over the fumes of burning sulphur (sulphurous acid); in a few minutes it will be white.

## QUESTIONS.

194. Is sulphur an abundant element?

195. Is it ever found pure?

196. Is it soluble in water?

197. What is understood by the term sublimed sulphur, or flowers of sulphur?

198. What is a sulphuret?

199. If you apply a piece of solid sulphur to red-hot iron, what is formed?

200. Describe the process by which they obtain sulphur in Sicily?

201. Do you remember how many tons of sulphur Great Britain consumed in 1839?

202. Describe the experiment which illustrates the bleaching property of burning sulphur?

203. Why does sulphur, when thrown on a fire, extinguish it?

204. Has it any effect on sour wine?

205. What is meant by sulphur seals?

206. Enumerate some of its important uses?

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445 to 9

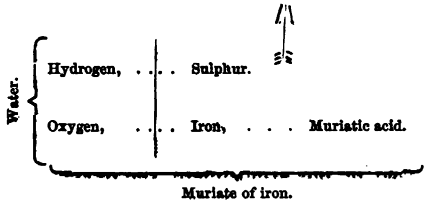
## SULPHURETTED HYDROGEN.

54. When sulphur unites with hydrogen in the proportion of one hyd. to sixteen sulph., sulphuretted hydrogen is formed. This gas, which has an extremely offensive odour, similar to a decomposed egg, which contains this gas, is nearly twice as heavy as our atmosphere, and is *extremely destructive* to animal life *when breathed*. These *two* properties render it a useful agent for destroying rats: this is accomplished by pouring the gas into their holes. It is combustible, and burns with a pale blue flame. When ignited in a close glass jar, there is a deposition of sulphur on the sides of the vessel. It is decomposed by our atmosphere, the oxygen of which unites with its hydrogen to form water, the sulphur being left behind. This is the origin of the sulphur which is found near mineral springs. The disagreeable smell which arises from drains arises partly from the presence of the same gas. Though so unpleasant, it possesses important medicinal properties. This is the case with the waters of Harrowgate, Aix-la-Chapelle, and Lucan, near Dublin. These are termed sulphurous spas.

55. Sulphur heated with potash (composed of potassium and oxygen) unites with the potassium, which is here called a base, and forms *sulphuret of potassium.* In this way sulphur may be combined artificially with most of the metals (*vide* exper. 48); but many of the metallic sulphurets are found in abundance, native (naturally formed).

*Experiment* 50.—If we pour some muriatic acid and water, termed diluted, on sulphuret of iron, the following change takes place:—The water is decomposed (*vide* exper. 28); its hydrogen unites with the sulphur to form sulphuretted hydrogen, which passes off as a gas. The oxygen seizes the iron, forming oxide, which unites with the muriatic acid. In this way the gas can be prepared for experiment.

Fig. 10.



As this gas is rapidly absorbed by cold water, it is advisable, when collecting it in the pneumatic trough, to use *warm* water.

56. Gold and silver, though not affected by being exposed to oxygen—hence called non-oxidizable metals—are tarnished by the sulphuretted hydrogen which is generally mixed with our atmosphere. It is this combination that renders plate-powder necessary.

57. This gas has the remarkable property of decomposing many metallic salts—its sulphur uniting with the metal forming a sulphuret, variously coloured according to the metal; thus lead forms a deep brown sulphuret, antimony orange, and arsenic a canary yellow. On this account the chemist employs sulphuretted hydrogen to detect the presence of certain metals. It is then termed a *re-agent.*

*Experiment* 51.—Write with a solution of sugar of lead, acetate of lead; this will be invisible; when exposed to the action of sulphuretted hydrogen, it becomes visible as the sulphuret of lead is formed. This is termed a *sympathetic* ink, many of which will be noticed.

## QUESTIONS.

207. In what proportions do sulphur and hydrogen unite to form sulphuretted hydrogen?

208. What does its odour resemble?

209. Why can it be employed for killing rats?

210. When this gas is burned in a close vessel what ensues?

211. What is a sulphurous spa?

212. How is sulphuret of potassium prepared?

213. What is a native sulphuret?

214. When we pour dilute muriatic acid on sulphuret of iron, why is sulphuretted hydrogen formed?

215. Why is warm water used in the pneumatic trough?

216. What effect has this gas on gold and silver?

217. What do we understand by calling this gas a re-agent?

218. When we write with sugar-of-lead solution, why does this gas render it visible?

## PHOSPHORUS.

58. This peculiar element is chiefly of animal origin. Its name is derived from the Greek *φως*, light, and *φερω*, to carry, as it emits light which is visible in the dark. It was accidentally discovered in 1677, by Brandt, an alchemist of Hamburg. In 1774, the celebrated chemist Scheele, of Sweden, ascertained that it could be obtained from the bones of the higher animals. From this source it is procured in the present day, by the following process (which is, perhaps, a little too difficult for a very young pupil):—Bones (which are principally composed of *gelatin*, (*animal jelly*,) *lime*, and *phosphoric acid*, i.e. *oxygen* and *phosphorus*) are burned till they become white; they are then ground to fine powder. When exposed to fire, bones lose their gelatin, and the white mass principally consists of phosphoric acid and lime, as above; the compound is termed *phosphate of lime.* To obtain phosphorus from the powder, three parts are mixed with two of vitriol, and thirty of water. The vitriol, having a superior attraction or affinity for lime, takes *a portion* of it from the phosphate of lime, forming *sulphate of lime*, which is *precipitated*, i. e. falls to the bottom of the vessel. The *remaining* portion of lime in the solution unites with *all* the phosphoric acid, forming a salt, which is *soluble* in the liquid. When this is strained, the sulphate of lime is left behind. The strained liquor is then evaporated, *i.e.* boiled down till it becomes as

thick as syrup; it is then mixed with fine charcoal powder, chiefly composed of *carbon*. When this mixture is dried it is exposed in an *earthen* retort to a considerable heat. After some time the carbon of the charcoal takes oxygen from the phosphoric acid, thus leaving the *phosphorus* in a free state, which, passing over in the state of vapour, is made to pass through cold water. It lastly falls to the bottom of this vessel, as solid phosphorus. This is afterwards melted in *warm* water, and poured into glass tubes; when cold it is ready for sale, presenting the appearance of solid *transparent* cylinders; generally it is *yellow*.

59. It is so inflammable that it burns when exposed to our atmosphere; by the heat of the hand it bursts into flame, producing a more dreadful burn than red-hot iron. *Young persons should avoid it.* It is preserved by keeping it in bottles containing *water*, and not exposed to light. When required for experiment, it should be cut *under* water: this is easily done, as it is as soft as wax.

60. Phosphorus combines with oxygen, hydrogen, sulphur, and some of the metals.

With oxygen it forms a reddish white oxide of phosphorus, which is formed by exposing it, while contained in water, to the action of light. The effect is produced by the air, which is always mixed with water. The oxide has a reddish tinge.

61. Phosphorus has so great an attraction for oxygen that it will release it from many of the metallic salts, thus reducing the metals to their metallic state. The

most convenient plan for applying phosphorus to illustrate this fact, is to dissolve a small portion in sulphuric ether—the size of a pea in an ounce of ether.

*Experiment* 52.—Write with a solution of nitrate of silver; if the page be held over the mouth of the bottle containing the phosphorized ether, the writing becomes visible as the silver is reduced.

This should be *particularly* contrasted with exper. 35, where hydrogen plays the same part.

*Experiment* 53.—Rub a small portion of the phosphorized ether on the hands or face, in the dark it becomes visible—*this is extremely harmless.*

*Experiment* 54.—Plunge an ignited piece of phosphorus into oxygen, it bursts into a most brilliant flame; or, drop it into a glass vessel containing warm water, and from a bladder, furnished with a stopcock, force oxygen upon it. This presents a splendid illustration of combustion under water.

## QUESTIONS.

219. What is the derivation of phosphorus?

220. By whom was it discovered, and in what year?

221. Who discovered that it could be abundantly obtained from bones?

222. What are bones principally composed of?

223. When bones are burned what portion is destroyed?

224. We say that phosphate of lime is left, what does it consist of?

225. To procure phosphorus sulphuric acid is added, what portion of the phosphate of lime does it attack?

226. When we say the sulphate of lime thus formed is *precipitated,* what is implied by this term?

227. When the strained liquor is boiled with charcoal, and then exposed to considerable heat, what changes does it effect?

228. How is it converted into its cylindrical form?

229. Why is it dangerous to take it in the hand?

230. When phosphorus is exposed to light while in water, why does its surface become reddish-white?

231. How do you form phosphorized ether?

232. When we expose silk touched with nitrate of silver to the fumes of phosphorized ether, why does the silver appear?

233. How can we burn phosphorus under water?

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## CARBON.

62. This very interesting element (derived from the Latin, *carbo,* coal) is so universally employed by Nature, that there is no locality where it cannot be procured. In *a perfectly pure* state it constitutes DIAMOND. When mixed with hydrogen and other bodies, it forms coal and various other *minerals.* It forms the principal portion of *a plant,* and enters into the formation of the *animal* structure. Before we consider it in its impure state as CHARCOAL, a few observations on the diamond may be interesting.

Up to the present time only two places have yielded this extraordinary treasure—a portion of the Indian peninsula and of Brazil, where a slave receives his liberty if he find a diamond weighing seventeen and a half carats. It is valued in the arts for its extreme *hardness,* and in the circle of fashion for its *brilliancy.*

The rate at which it is sold when polished is remarkable :—a carat weighs only four grains, and sells for eight pounds; two carats are worth thirty-two pounds; three carats, seventy-two pounds; and four carats, one hundred and twenty-eight pounds. The increase of price is arranged thus: the weight of the carats is *doubled*, and the *square* of the product is *multiplied* by two pounds. When the weight amounts to twenty carats the purchasers are but few. One of the largest diamonds that has been discovered belongs to the rajah of Mattan in the East Indies. It is of the *purest water*, and weighs three hundred and sixty-seven carats. It was discovered about one hundred years since. The emperor of Russia possesses one weighing one hundred and ninety-three carats. It is as large as a pigeon's egg, and was purchased by the Empress Catherine for ninety thousand pounds, with an annuity to a Greek merchant of four thousand. Its history is worth relating :—It was one of the eyes of the statue of Sheringan in the temple of Brama. A French grenadier who served in the Malabar army contrived to steal this gem, and reached Madras in safety, where he sold it for two thousand pounds to a ship-captain, who disposed of it to a Jew for twelve thousand pounds; it passed then into the hands of the Greek merchant, and ultimately was purchased by Catherine. One of the finest diamonds belongs to Louis Philippe of France. It weighs one hundred and thirty-six carats, and is valued at one hundred and sixty thousand pounds. It is named the Regent or Pitt diamond.

63. The art of cutting diamonds by rubbing them against each other, or polishing them with their own powder, was discovered by Louis de Berquen in 1476. The diamond *dust* sells for one hundred and sixty pounds an ounce. They are generally colourless and transparent. When coloured, they are yellow, green, blue, rose, or pink—the latter sometimes exceed in price the transparent. Diamonds are found in loose earth, a little below the surface of the soil.

64. That the DIAMOND is CARBON will be evident from the following statement. Sir Humphrey Davy placed a diamond, heated to redness, in a close vessel containing *pure oxygen*. It was then placed in the focus of a powerful lens (burning-glass), brilliant combustion ensued: the diamond disappeared, forming with the oxygen the invisible gas, CARBONIC ACID. On referring to the article on oxygen, it will be seen that when a piece of ignited *charcoal* was immersed in it the light was splendid, and the resulting compound was CARBONIC ACID.

Monsieur Morveau of France enclosed a diamond in a piece of iron: this was exposed to an intense degree of heat: when the cavity was subsequently opened, the diamond had disappeared, while the surface of the cavity was converted into STEEL, which is chemically termed *carburet* of *iron*. Some suppose that steel owes its hardness to the iron having absorbed the pure portion of charcoal, DIAMOND, which is employed in preparing it.

The received opinion is, that the difference between diamond and charcoal depends on crystallization.

## QUESTIONS.

234. What is the derivation of carbon?
235. Is it abundant?
236. What is the purest specimen?
237. What is it termed in its impure state?
238. What countries yield diamonds?
239. How much is a carat?
240. Do you remember the rule for pricing them?
241. Which is the largest diamond?
242. How many carats does the Regent weigh?
243. How are they cut, and when was the art discovered?
244. What are the usual colours?
245. How did Davy prove that diamond was carbon?
246. What did Morveau accomplish by heating diamond enclosed in iron?
247. What is the chemical name of steel?

65. Carbon tolerably pure is found abundantly in the mineral kingdom—particularly in the various varieties of COAL. Anthracite or Kilkenny coal is mineral charcoal—differing from common coal in containing scarcely any trace of *bitumen*. It consequently burns without flame or smoke. COKE principally consists of *carbon*. It is obtained from gas retorts, after all the volatile portions have been expelled by fire. It produces an intense heat, and burns without smoke, which circumstance renders it valuable for railroads.

CHARCOAL is vegetable carbon. It is obtained by exposing wood to an intense heat in covered vessels, as will be seen in the article on ACETIC ACID; or by igniting piles of wood, *covered with earth*, to screen it from the full action of the atmosphere, which would otherwise totally consume it. In France, charcoal—termed *charbon*—is prepared on an extensive scale, as it is generally used instead of coal.

66. Wood charcoal has neither taste nor smell. It is a bad conductor of heat, on which account it is employed for covering small furnaces and steam-pipes. If *air be excluded*, it will resist the strongest heat without suffering any change. It is not affected *by water*, on which account water-casks are frequently *charred* inside. "About sixty years since a quantity of oak stakes were found in the bed of the Thames, in the very spot where Tacitus says that the Britons fixed a vast number of such stakes to prevent the passage of Julius Cæsar and his army. These stakes were *charred* to a considerable depth, retained their form completely, and were firm at the heart."—*Dr. Ure*. It is, perhaps, not generally known that most of the houses in Venice stand upon *charred* piles of wood. The most remarkable illustration of its imperishable character is the fact that the beams of the houses in Herculaneum, which were charred by the burning lava, A. D. 79, appear like *the charcoal of this day*. (The author has a specimen which was brought from the spot by the Rev. Robert Handcock.)

67. Charcoal is extensively used in the arts. It enters into the composition of gunpowder, which generally consists of seventy-five parts of nitre, fifteen of charcoal, and ten of sulphur. The charcoal for

gunpowder is made of alder, willow, or dogwood, exposed to heat in close iron cylinders. The bark is previously removed, as it is this portion alone which crackles when charcoal is united. We will return to gunpowder when treating of POTASH.

The engraver uses charcoal and oil for *planishing* copper-plates. The manufacturer employs it with iron in making steel; and in refining sugar it is used for removing colour. From its affinity for oxygen, the chemist sometimes selects it as the agent for removing oxygen.—(*Vide* phosphorus.) In the laboratory and manufactory wood and bone charcoal are employed. In its fine state, as in *ivory-black* and *lamp-black*, it forms the basis of black paints, Indian ink, and printer's ink.

*Experiment* 55.—Place in a crucible, two pieces of wood, *with* and *without* bark, cover them with sand, and expose them to a strong heat. After some time, when the vapours cease, *charcoal* will be found in the crucible. On igniting the two different specimens, that which contains bark will alone crackle.

68. Lowitz of Petersburgh discovered that charcoal removes offensive odours from animal and vegetable substances, and counteracts putrefaction. This constitutes an important feature in domestic economy, for removing colour from vinegar, and odours from meat and water. Small pieces red hot are to be thrown into the vinegar or the vessel containing meat; the water is to be filtered through *three* or *four* inches of powdered charcoal, placed on a stratum of fine pebbles and sand, lying on a plate of *burnt* clay perforated

with holes, (this can be prepared at the pipe-maker's)—such a filter will stand for many years.

In the article on carbonic acid it will be seen that when *charcoal* is ignited, it forms with the *oxygen* of the air, *carbonic acid,* a subject of much importance. (*Vide* 64.) Carbon unites with sulphur and phosphorus. It combines with *nitrogen,* forming the basis of prussic acid. United with *iron,* it forms *steel* and *black-lead,* (*plumbago,*) as will be seen in part third; and with hydrogen it combines in two definite proportions, making *carburetted* and *bicarburetted* hydrogen.

## QUESTIONS.

248. What is coal principally composed of?
249. How does anthracite differ from common coal?
250. How is coke prepared?
251. Why is it used on railroads?
252. Describe the two methods for preparing charcoal?
253. Why are the piles of wood covered with earth?
254. Why is it used for covering steam-pipes?
255. Is it affected by fire if confined in close vessels?
256. Relate some of the facts connected with *charred* wood.
257. What is mixed with charcoal in making gunpowder?
258. What woods are used in preparing the charcoal?
259. Why is it employed in refining sugar?
260. In obtaining phosphorus, what part does the charcoal play?
261. How would you prepare charcoal on a small scale?
262. Who discovered that it removed offensive odours?
263. How is a charcoal filter prepared?
264. What does it form when ignited?
265. When united with hydrogen what does it form?

## CARBURETTED HYDROGEN.

69. This gas is composed of one volume of the vapour of *carbon* and two of hydrogen. It is colourless and inodorous. It burns with a yellow flame like a candle, and is easily procured from stagnant pools or ditches by

*Experiment* 56.—Place the mouth of a glass vessel, full of water, in the stagnant pool; stir the bottom with a stick and the gas will ascend into the inverted vessel, this may be called a natural pneumatic trough. This gas is evidently produced, particularly in warm weather, by the action of the *hydrogen* of water on decaying vegetable matter which parts with its *carbon*. *Carbonic acid* is also present from the *oxygen* of the water uniting with another portion of *carbon*. The FIRE-DAMP of mines is a gas similar to that of ditches. Against its destructive influence there is the *safety-lamp* of Sir H. Davy. Without entering minutely into the subject we may easily explain its principle.

*Experiment* 57.—By holding a piece of *fine* wire gauze *in* the flame of a candle it will be seen that though the products of combustion pass through the gauze, THE FLAME DOES NOT; this arises from the metallic gauze *cooling* the inflammable hydrogen of the tallow *below* the temperature at which its combustion ensues.

Founded on such experiments, Sir H. Davy surrounded the taper with fine iron or copper gauze, so that no communication should exist between the flame and the external fire-damp, if present, except through the meshes of the gauze. By this invention alone, without any of his other splendid discoveries, he would have left behind him an undying name.

This carburetted hydrogen burns with a brighter flame than pure hydrogen, as it contains *carbon*. The increased brilliancy arises from the *carbon being liberated* at the moment the *hydrogen* burns in the oxygen of the air to form water. The *carbon* is then ignited, diffusing the vivid light by consuming another portion of oxygen from the atmosphere, forming *carbonic acid*. The *products of* its *combustion* are, therefore, *water* and *carbonic acid*.

We obtain the same compounds by burning candles, coal, and gas—*hydrogen* and *carbon* being present.

### QUESTIONS.

**266. What is carburetted hydrogen composed of?**

**267. From what source can we obtain it naturally?**

**268. How is it formed in stagnant pools?**

**269. Carbonic acid is also mixed with it—what produces it?**

**270. What is the fire-damp?**

**271. Explain the principle of Davy's lamp.**

**272. Why does this gas burn with a brighter flame than pure hydrogen?**

**273. By burning it, we form water and carbonic acid—explain this process.**

## BICARBURETTED HYDROGEN.

70. Coal Gas is a familiar illustration of this compound; it differs from carburetted hydrogen in containing two volumes of the vapour of *carbon* with two of *hydrogen:* on this account it burns with a brighter flame. It is generally obtained by *dry distillation*, or carbonization in iron retorts, of vegetable and animal substances, or *coal* which is of vegetable origin. Those in use are *coal*, especially the *cannel coal*, *oil*, *resin*, (improperly called *rosin*,) and the liquid resin *tar*. We will now endeavour to point out the changes that take place during the distillation of coal: it has been proved by experiments that the coal should not be introduced into the retorts until they are heated to a cherry red; at this temperature a portion of the tar is converted into gas instead of passing over in the state of vapour; this operation is generally continued for five or eight hours. The residuum in the retort is termed Coke, upon an average

| | |
|---|---|
| **1lb. good coal yields** | **4 cubic feet gas.** |
| **1lb. oil yields** | **15 cubic feet gas.** |
| **1lb. tar yields** | **12 cubic feet gas.** |
| **1lb. resin yields** | **10 cubic feet gas.** |

as coal is the cheapest it is now generally used.

71. As the distillation of coal yields tar, ammonia, sulphuretted hydrogen and carbonic acid with the illuminating gas, *bicarburetted hydrogen*, it is necessary

to purify it. Without entering into a minute description of the process, the following statement may be deemed intelligible. The heated retorts, which are set in brickwork with their mouths presented to the workmen, are half filled with coal, the doors are then carefully closed by fire-clay ; in a short time the coal yields up its volatile compounds, which pass into pipes that first ascend and then descend by bending into a large cast iron tube half filled with water, the bent tubes are styled *dip pipes*, (No. 1.) the water cylinder is named the *hydraulic main*, (No. 2.) The ends of the dip pipes are immersed in the water, which *condenses* a portion of the tar and ammonia—while the gas passes on by a pipe to the *condenser*, (No. 3,) which consists of a number of vertical pipes surrounded by cold water ; these are very palpable in the gas works of this city. The tar cistern (No. 4,) is connected with these pipes, in which the tar and ammonia are condensed after coursing through the vertical pipes—the carburetted hydrogen, carbonic acid, and sulphuretted hydrogen then pass to the *purifier*, (No. 5,) which contains a thick mixture of lime and water called cream of lime, with a revolving spindle set with vanes—the lime seizes the carbonic acid, (*vide* exper. 1) and abstracts the sulphur from the hydrogen, which unites with the illuminating gas, now purified, that passes through a most ingenious instrument, the gas meter, (No. 6,) which registers the quantity as it takes its course towards the gas-holder or gasometer, (No. 7.) From this vesssel the citizens are supplied. It is deserving of notice that the iron retorts are destroyed by the vapour of *carbon* uniting with the *iron*, forming *artificial plumbago* or *black lead*, which is extensively used in galvanic experiments.

*Experiment* 58.—Fill the bowl of a tobacco-pipe with pounded coal, cover up the mouth with a lute of fire-clay, insert the bowl *into* the fire, and in a short time the gas can be ignited when issuing from the small tube.

72. Coal gas was first obtained by the Rev. Dr. Clayton, in 1739. Mr. Murdock, engineer to Messrs. Bolton and Watt, was the first person who publicly used it as a substitute for oil, in 1802. In that year there were illuminations for the peace of Amiens: Mr. Murdock on that occasion, in the Soho factory, displayed, for the first time, gas-light. Dublin was not illuminated with gas till 5th October, 1825.

### QUESTIONS.

274. How does bicarburetted hydrogen differ from carburetted?

275. How is it generally obtained?

276. Why is the retort made red hot before the coal is introduced?

277. Which yields most gas—coal, oil, tar, or resin?

278. Why is it necessary to purify coal gas?

279. Can you describe the changes that take place as the gas goes to the gasometer?

280. What is formed on the inside of the retort?

281. Who first used coal gas?

282. In what year was Dublin illuminated?

END OF FIRST PART.

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